Attached Payloads Accommodation Handbook

International Space Station Program

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INTERNATIONAL SPACE STATION

ATTACHED PAYLOADS ACCOMMODATION HANDBOOK

PREFACE

This Payloads Accommodation Handbook addresses resource and physical accommodations available to the various scientific or technology experiments that attach to the standard unpressurized Payload Attach System of the International Space Station.

The purpose of this handbook is not to provide requirements but sufficient information on the interfaces, accommodations, capabilities, performance characteristics, and constraints specific to attached payloads at the Integrated Truss Segment (ITS) Starboard 3 and at the ITS Port 3 locations. This will enable Payload Developers to understand and evaluate design concepts of how Attached Payloads will be accommodated by the ISS.

INTERNATIONAL SPACE STATION

ATTACHED PAYLOADS ACCOMMODATION HANDBOOK

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INTERNATIONAL SPACE STATION PROGRAM

ATTACHED PAYLOADS ACCOMMODATION HANDBOOK

LIST OF CHANGES

All changes to paragraphs, tables, and figures in this document are shown below:

SSCBD	ENTRY DATE	CHANGE	PARAGRAPH(S)
		Revision A	All

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1.0 INTRODUCTION

The International Space Station (ISS) is an international, Earth–orbiting, research facility. Its mission is to conduct scientific, technological, and commercial application research in a microgravity environment, on an orbiting platform, with an emphasis on long duration activities. People and organizations conducting scientific and commercial research and development activities on board the ISS are referred to as payload developers. Payload developers may originate from government, academic or commercial sectors of the United States (U.S.) or international participants.

This Payload Accommodations Handbook (PAH) serves as a guide for users of ISS resources allocated to four external attach sites on the Integrated Truss Segment (ITS) Starboard 3 (S3) and two external attach sites on the ITS Port 3 (P3). Experiments and associated equipment are generally referred to as Attached Payloads. The physical interface between the ISS and the Attached Payloads will occur at a Payload Attach System (PAS) site or an Unpressurized Cargo Carrier Attach System (UCCAS) location on ITS S3 or ITS P3 respectively. All four PAS sites and the two UCCAS sites support the transfer of structural loads, power and data across the PAS/UCCAS interface and are designed to support multiple cycles of robotic payload installation and removal. All PAS and UCCAS sites are also configured for remotely actuated connection and disconnection of payloads to and from ISS resources and services.

The Attached Payload Accommodations Handbook is organized as follows:

A. Section 1.0 provides an introduction to this document.

B. Section 2.0 lists applicable documents.

C. Section 3.0 provides an overview of accommodation features available to the four PAS sites, located on the ITS S3, which have been designated as primary Attached Payload sites, and the two UCCAS sites located on the ITS P3.

D. Section 4.0 provides system description, interfaces, and payload accommodations for transportation and on–orbit as related to U.S. Truss Attached Payloads only.

E. Appendix A identifies abbreviations and acronyms used in this document.

F. Appendix B provides a glossary of terms and definitions.

1.1 PURPOSE

The purpose of this PAH is to provide sufficient information on the interfaces, accommodations, capabilities, performance characteristics, and constraints specific to payloads attached to the ISS Truss at the S3/P3 locations. This will enable attached payload developers to evaluate design concepts of payload equipment between the ISS and four PAS sites at the ITS S3 and the two

UCCAS sites at the ITS P3. A payload is a discrete set of equipment, software and/or other items that are designated and treated as a collective whole in support of one or more experiments or commercial objectives. ”Attached Payload” is a generic term used to identify those scientific and technology experiments or collection of experiments packaged specifically for ISS integration and operation in the unpressurized near earth orbit environment.

1.2 SCOPE

This document addresses interfaces and accommodations related to U.S. Truss Attached Payloads on the PAS site at the ITS S3 and/or the UCCAS at the ITS P3 to be developed and integrated by any International Partner. The interfaces defined in this document apply to transportation and on–orbit phases of the payload mission cycle. The following represents the order of precedence regarding document relationships and management as contained in this Attached Payloads Accommodation Handbook:

- SSP 57003 ”Attached Payload Interface Requirements Document”
  - Interface Requirements
  - Safety Requirements (points to NSTS 1700.7)
  - Verification Requirements
- SSP 57004 ”Attached Payload Hardware Interface Control Document”
  - Element Specific Resource and Interface Capabilities
  - Fill–In Tables for payload Physical Interface and Resource Requirements
  - Applicability Matrix
  - Exceptions Process
- SSP 42131 ”Integrated Truss Segments P3 and S3 to Attached Payloads and Unpressurized Cargo Carriers (UCC) Standard ICD”
- SSP 57021 ”Attached Payloads Accommodation Handbook (PAH)”

Attached Payload ground handling, processing, and ground transportation requirements are specified in K–STSM–14.1, Launch Site Accommodations Handbook for Shuttle Payloads, and KHB 1700.7, Space Shuttle Payload Ground Safety Handbook. The reader is referred to NSTS 21000–IDD–ISS, Shuttle Orbiter Interface Definition Document for International Space Station, for Attached Payload requirements related to transportation in the Space Shuttle. Also, information contained within this document are not requirements and is applicable to the fully assembled ISS unless otherwise noted. In the event of conflict between SSP 57021 and SSP 57003, the content of SSP 57003 supersedes. The units for dimensions on drawings and figures are in inches, unless otherwise specified.

2.0 DOCUMENTATION

The following includes specifications, standards, guidelines, procedures, handbooks and other special publications. These documents form a part of this document to the extent specified herein. Payload Developers are responsible for only those documents cited in SSP 57003. Reference to these documents in this document is to be considered as information only.

2.1 APPLICABLE DOCUMENTS

Document No.	Title
COL–RIBRE–TN–1357	Interface Definition Between the External Payload and Attached Pressurized Module
JCX–95061	JEM–EF/Payload Standard ICD
JSC 20466	EVA Tools and Equipment Reference Book
KHB 1700.7	Space Shuttle Payload Ground Safety Handbook
K–STSM–14.1	Launch Site Accommodation Handbook for Shuttle Payloads
MIL–STD–1553	Digital Time Division Command/Response Multiplex Data Bus
MSFC–HDBK–527 /JSC 09605	Materials Selection List for Space Hardware Systems
NASA TP–2002–210780	The New NASA Orbital Debris Engineering Model ORDEM2000
NSTS–13830	Implementation Procedure for NSTS Payloads System Safety Requirements Document
NSTS 1700.7	Safety Policy and Requirements for Payloads Using the Space Transportation System
NSTS 1700.7 ISS Addendum	Safety Policy and Requirements for Payloads Using the International Space Station
NSTS 2100–IDD–ISS	Shuttle Orbiter Interface Definition Document for International Space Station
SN–C–0005	NSTS Contamination Control Requirements Manual
SP–M–229	Addendum Specification to Prime Item Development Specification for Integrated Truss Element P3 for Integrated Truss Segment (ITS) S3
SP–M–235	Prime Item Development Specification for Integrated Truss Segment P3
SP–M–602	Configuration Item Specification for the Payload Attach System

Document No.	Title
SP–M–603	Configuration Item Specification for the Unpressurized Cargo Carrier Attach System
SSP 30219	Space Station Reference Coordinate System
SSP 30243	Space Station Requirements for Electromagnetic Compatibility
SSP 30245	Space Station Electrical Bonding Requirements
SSP 30256:001	Extravehicular Activity Standard Interface Control Document
SSP 30312	Electrical, Electronic, and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program
SSP 30420	Space Station Program Induced Plasma Environment
SSP 30423	Space Station Approved EEE Parts List
SSP 30425	Space Station Program Natural Environment Definition for Design
SSP 30426	External Contamination Control Requirements
SSP 30482 (V1)	Electrical Power Specifications and Standards, Vol. 1: EPS Performance Specifications
SSP 30482 (V2)	Electrical Power Specifications and Standards, Vol. 2: Consumer Constraints
SSP 30512	Ionizing Radiation Design Environment
SSP 41000	System Specification for the International Space Station
SSP 42004	Mobile Servicing System to User (generic) Interface Control Document
SSP 42131	Integrated Truss Segments P3 and S3 to Attached Payloads and Unpressurized Cargo Carriers Interface Control Document
SSP 50005	International Space Station Flight Crew Integration Standard (NASA STD 3000/T) Document
SSP 50112	Operations Summary Document
SSP 50254	Operations Nomenclature
SSP 52000–IDD–EPP	EXPRESS Pallet Interface Definition Document
SSP 52000–PAH–EPP	EXPRESS Pallet Payload Accommodation Handbook
SSP 52005	ISS Payload Flight Equipment and Guidelines For Safety Critical Structures
SSP 52050	Software Interface Control Document Part 1, International Standard Rack to International Space Station

Document No.	Title
SSP 52055	EXPRESS Pallet System Development Specifications
SSP 57003	Attached Payload Interface Requirements Document
SSP 57004	Attached Payload Hardware Interface Control Document Template
SSP 57020	Pressurized Payloads Accommodations Handbook
SSP 57916	Generic Payload Microgravity Control Plan
SSQ 21637	Connectors and Accessories, Electrical, Umbilical Interface, Environmental, Space Quality, General Specification for
STM–0006	Coating Thermal Control Potassium Silicate – Zinc Oxide
STP 0016	Coating, Thermal Control, Potassium Silicate – Zinc Oxide, Application of

2.2 REFERENCE DOCUMENTS

Document No.	Title
ICD–2–19001	Shuttle Orbiter Cargo Standard Interface (CORE)
JSC 27260	Decal Process Document and Catalog
JSC 36044	Operations Nomenclature
JSC SPEC–SP–R–0022	General Specification, Vacuum Stability Requirement of Polymetric Materials for Spacecraft Applications
MIL–HDBK–1553	Digital Time Division Command/Response Multiplex Data Bus Handbook
MIL–STD–461	Electromagnetic Emission and Susceptibility Requirements for Control of Electromagnetic Interface
MIL–STD–462	EMI Characteristics, Measurement of
MIL–STD–1189	Standard Department of Defense Bar Code Symbology
MSFC–STD–275	Marking of Electrical Ground Support Equipment, Front Panels, and Rack Title Plates
NSTS 07700, Volume XIV	Space Shuttle System Payload Accommodations
NSTS 14046	Payload Verification Requirements
NSTS 18798	Interpretations of NSTS Payload Safety Requirements
SP–M–600	Configuration Item Specification for the Capture Latch Assembly

Document No.	Title
SP–M–601	Configuration Item Specification for the Umbilical Mechanism
SSP 30233	Space Station Requirements for Material and Processes
SSP 30237	Space Station Requirements for Electromagnetic Emission and Susceptibility Requirements
SSP 30238	Space Station Electromagnetic Techniques
SSP 30550	Space Station Robotic System Integration Standards Vol. 1 Robotic Accommodations Requirement
SSP 50006	Caution and Warning Labels
SSP 50184	High Rate Data Link Physical Media, Physical Signaling & Protocol Specifications
SSQ 21655	Cable, Electrical, MIL–STD–1553 Data Bus, Space Quality, General Specification for Document

3.0 OVERVIEW

3.1 INTERNATIONAL SPACE STATION PAYLOAD ACCOMMODATIONS

Accommodations for external payloads, those operated outside of the pressurized volume, are provided at attach sites on the U.S. Truss, the Japanese Experiment Module Exposed Facility (JEM–EF) and the Columbus–EPF (External Payload Facilities). Accommodations for payloads on the JEM–EF and the Columbus–EPF are briefly discussed below to identify attach sites other than those available on the U.S. Truss. Reference is made to Figure 3.1–1, Element Orientation. The ITS provides the backbone structure for the ISS accommodating science and technology experiments; distribution trays for cables; providing for Extravehicular Activity (EVA) support equipment such as handholds and lighting; and providing for Extravehicular Robotic (EVR) accommodations using the Mobile Servicing System (MSS).

Accommodations for Pressurized Payloads are fully described in SSP 57020, Pressurized Payload Accommodation Handbook.

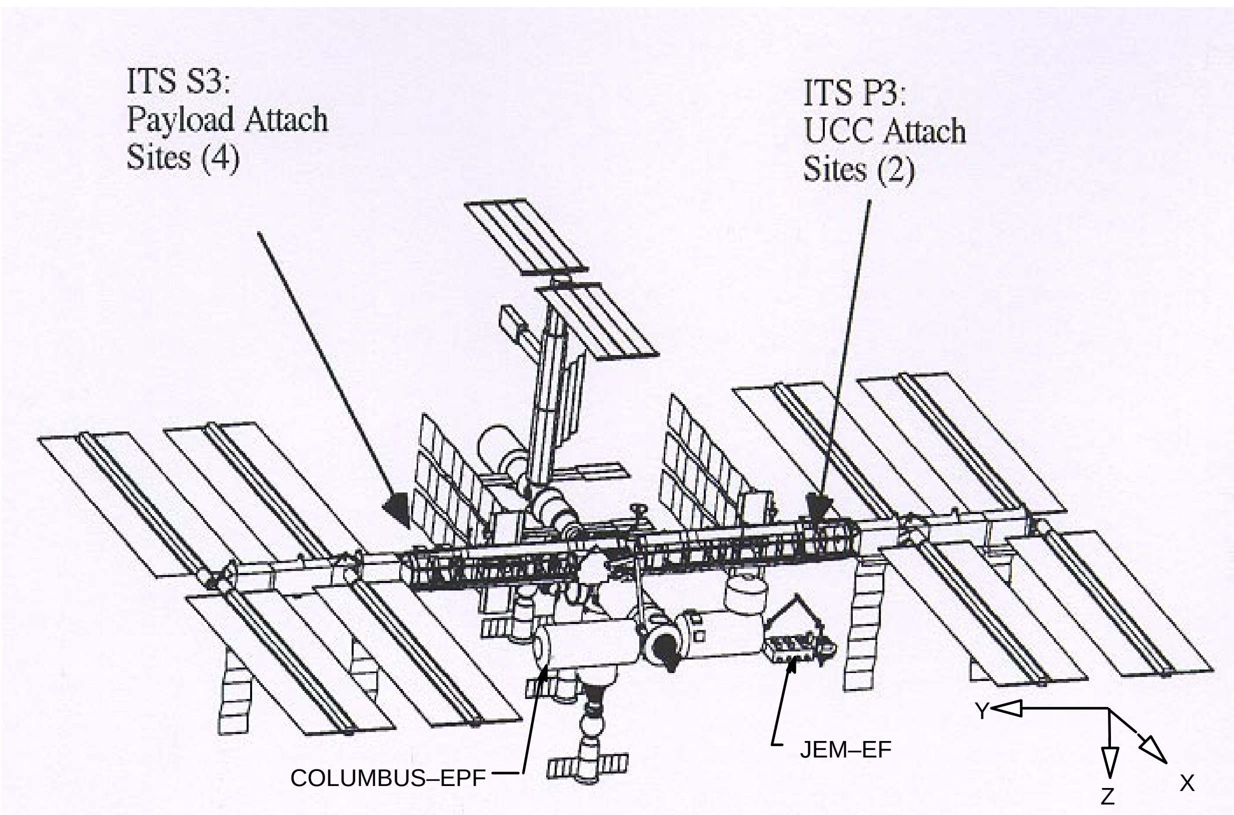


FIGURE 3.1–1 ELEMENT ORIENTATION

3.1.1 US TRUSS ATTACHED PAYLOAD/UNPRESSURIZED CARGO CARRIER ACCOMMODATIONS

In support of its stated purpose as a research platform in near–Earth orbit, the United States On–Orbit Segment (USOS) provides for installation and operation of experiments and logistics equipment at six external attach sites.

The USOS provides attach services at four Payload Attach System (PAS) sites located on the S3 segment and at two Unpressurized Cargo Carrier Attach System (UCCAS) sites located on the P3 truss segment. The six sites are configured to support multiple cycles of robotically assisted berthing and de–berthing of Attached Payloads/UCCs to and from the attach systems. The PAS/UCCAS assemblies are to be launched integral to ITS S3 and P3 and deployed by EVA as part of assembly operations. The PAS/UCCAS assemblies will be deployed and ready for use prior to launch of the Attached Payloads/UCCs.

The interfaces at the sites support the transfer of structural loads, power, commands and data. All six sites are configured for remotely actuated connection and disconnection of payloads to and from ISS resources and services.

The six sites will become operational at the conclusion of S3/P3 assembly operations and remain operational for the life of the ISS. The locations of the six external attach sites are detailed in Figures 3.1–1, 3.1.1–1, and 3.1.1–2. The attach sites (each mechanically identical) feature three Guide Vanes, a Capture Latch Assembly (CLA) and an Umbilical Mechanism Assembly (UMA). Each site has dedicated power and Command and Data Handling (C&DH) connections through the UMA.

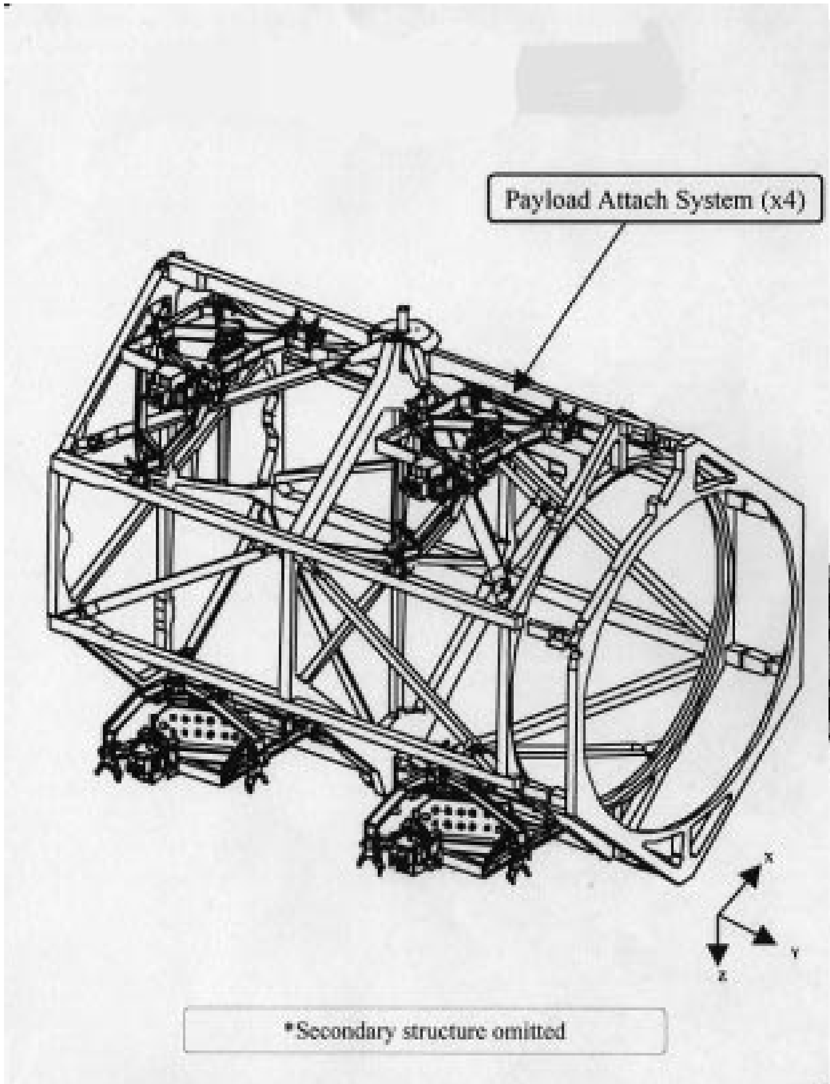


FIGURE 3.1.1–1 INTEGRATED TRUSS SEGMENT S3

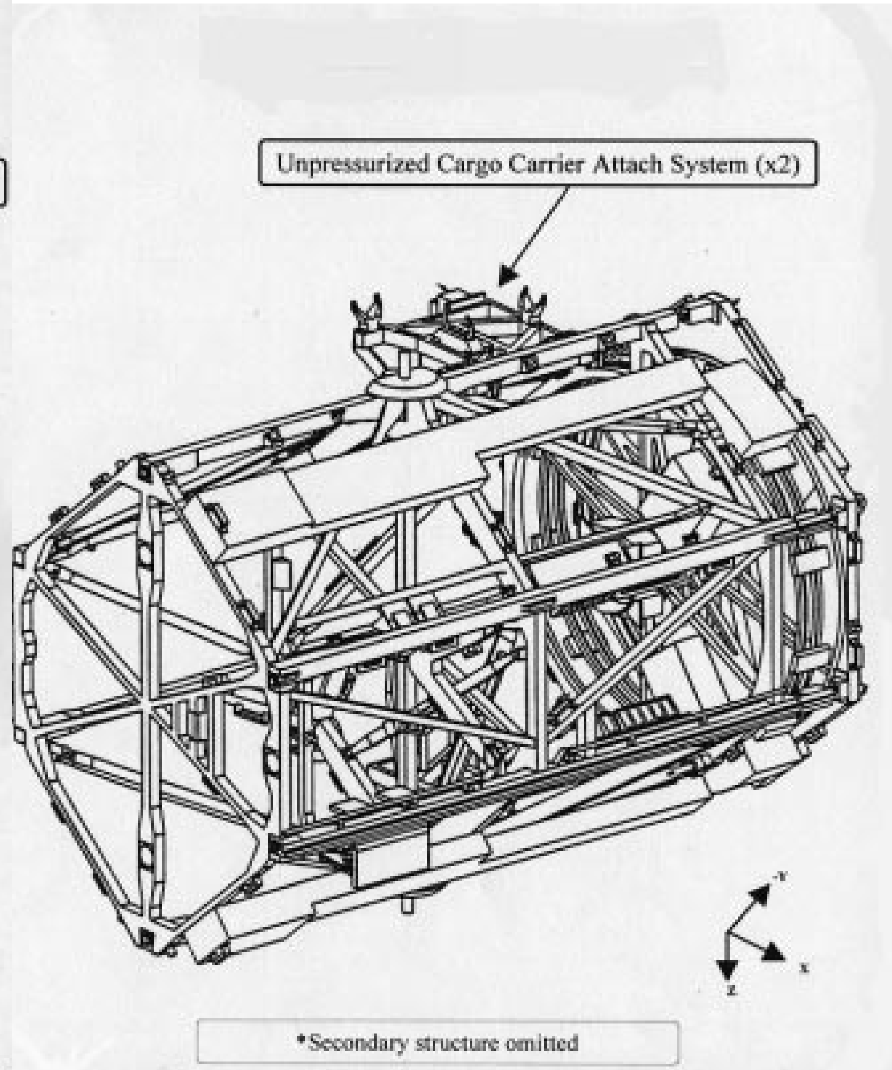


FIGURE 3.1.1–2 INTEGRATED TRUSS SEGMENT P3

3.1.2 JAPANESE EXPERIMENT MODULE EXPOSED FACILITY

The Japanese Experiment Module Exposed Facility (JEM–EF) is a facility (unpressurized work area) for conducting scientific observations, earth observations, and experiments in communications, physical and engineering sciences, materials processing, etc. in an environment exposed to space. JCX–95061, JEM–EF/Payload Standard ICD defines and controls the design of the interfaces that are to be provided by the JEM–EF for its payloads (referred to as ”EF payloads”). Figure 3.1.2–1 shows the configuration of the JEM–EF.

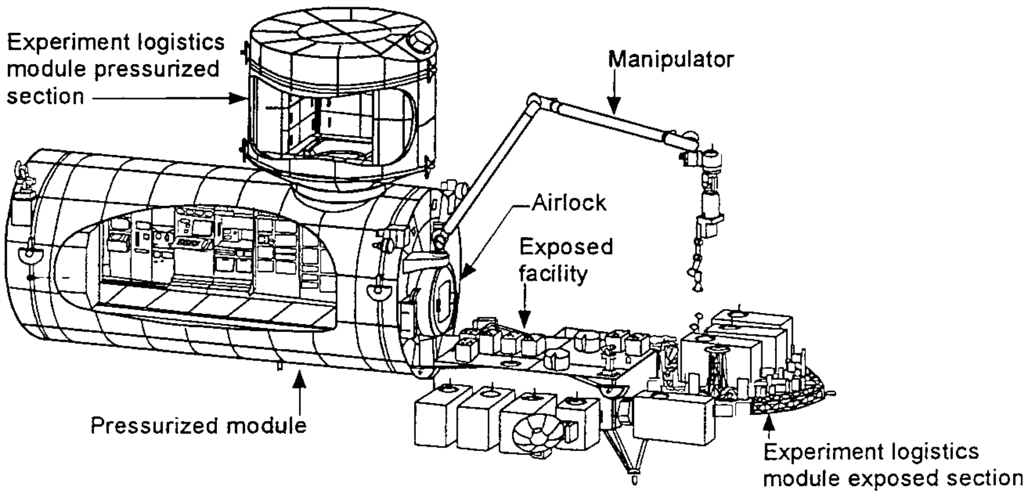


FIGURE 3.1.2–1 JEM PRESSURIZED MODULE AND EXPOSED FACILITY

3.1.3 COLUMBUS EXTERNAL PAYLOAD SUPPORT FACILITY

COL–RIBRE–TN–1357 describes/establishes the interface requirements and interface definitions between the Columbus External Payload (External Payload Facilities) and the starboard end cone (i.e., starboard side of Node 2) of the Columbus Module. The external payload is comprised of the payload instrument/instruments, the active part of the Flight Releasable Attachment Mechanism (FRAM) and the External Payload Assembly Adapter.

3.2 ATTACHED PAYLOADS DESCRIPTION

3.2.1 EXPRESS PALLET

An example of an Attached Payload is the Expedite the Processing of Experiments to ISS (EXPRESS) Pallet System (ExPS). SSP 52055, EXPRESS Pallet System Development Specification, establishes the requirements of the ExPS. This includes the EXPRESS Pallet

(ExP), the EXPRESS Pallet Adapter (ExPA), and the EXPRESS Pallet Control Assembly (ExPCA). A concept for the ExPS is presented in Figure 3.2.1–1.

The ExP provides a structural platform for the integration of ExPA mounted payloads. It will provide for a structural and mechanical interface with the S3 Truss Site, with a capability for EVR or EVA manipulation, connection, and attachment to structural, electrical, and data interfaces.

For additional information, reference should be made to the EXPRESS Pallet IDD and PAH (i.e., SSP 52000–IDD–EPP and SSP 52000–PAH–EPP).

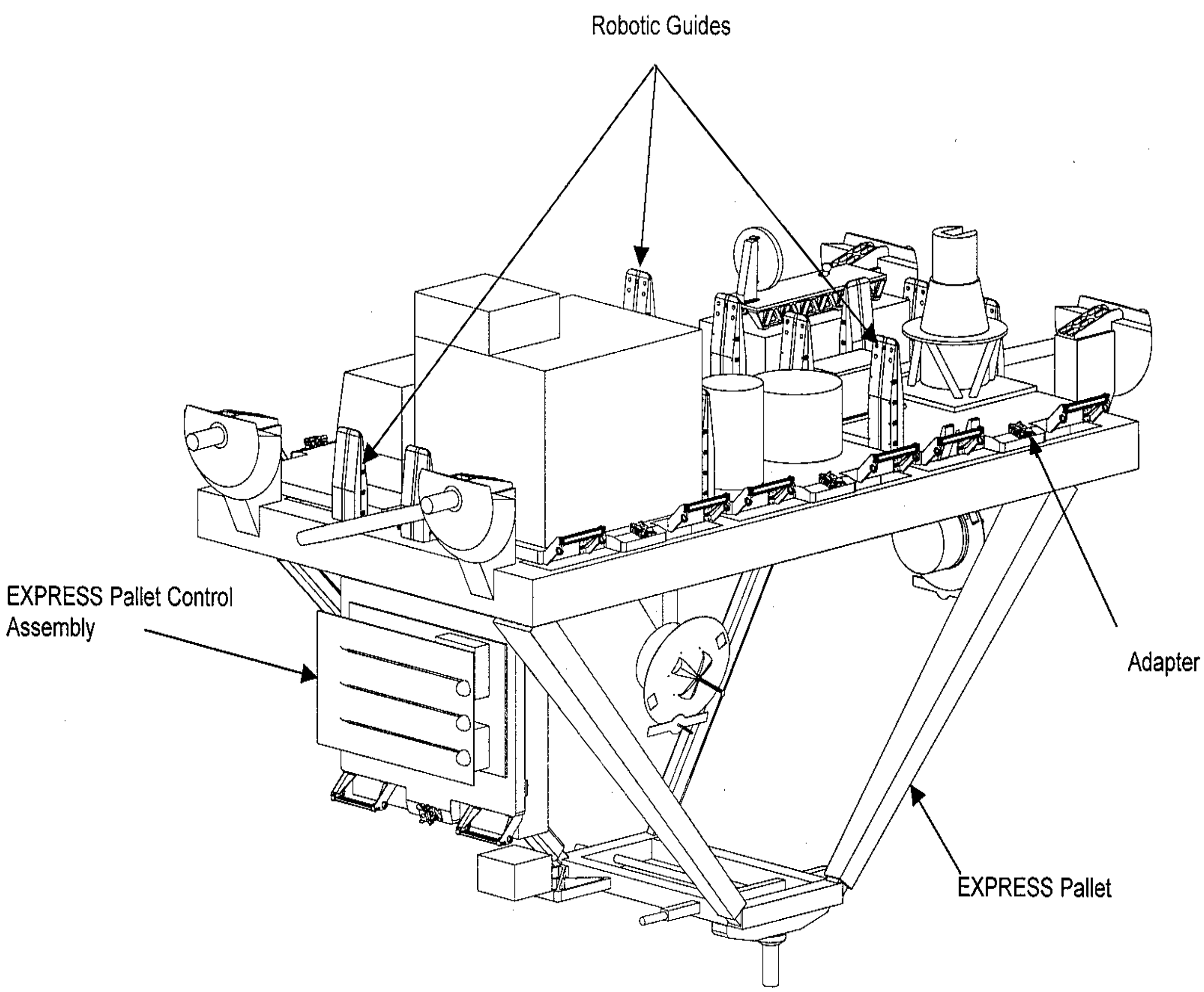


FIGURE 3.2.1–1 EXP SYSTEM

3.2.2 ALPHA MAGNETIC SPECTROMETER

Another example of an Attached Payload interfacing with the ITS S3, is the Alpha Magnetic Spectrometer (AMS) experiment. The AMS will have mounting, installation and attachment provisions on the ITS S3 with direct physical contact via the PAS. There will be interfaces and control process between the AMS (as an Attached Payload) and the primary components of the active PAS and the passive PAS. Figure 3.2.2–1 is an artist's concept of the EXPRESS Pallet and AMS located on the S3 site.

3.3 ATTACHED PAYLOAD TRANSPORTATION

Each Attached Payload is delivered to the Space Station by the Space Shuttle Orbiter using standard keel trunnion and longeron trunnion interfaces. The Attached Payload is removed from the Shuttle Orbiter payload bay Payload Retention Latch Actuators (PRLAs) using the Shuttle Remote Manipulator System (SRMS) interfacing with a grapple fixture on the Attached Payload. The Attached Payload is transferred to the Mobile Transporter (MT) using the Space Station Remote Manipulator System (SSRMS) Latching End Effector (LEE) interfacing with a compatible Shuttle grapple fixture, a Space Station Power Data Grapple Fixture (PDGF) or a Power Video Grapple Fixture (PVGF) mounted on the Attached Payload. For robotic handoff, the Attached Payload must provide a minimum of one grapple fixture for each robot. The Attached Payload to MSS interface provides structural support for the Attached Payload while attached to the Mobile Remote Servicer (MRS) Base System (MBS) Common Attach System (MCAS) and is physically similar to the interface with the Payload Attach System (PAS) on the Truss. The Mobile Transporter transports the Attached Payload to the desired position on the Truss for installation. The Attached Payload is installed on the Truss using the SSRMS, with the assistance of the External Berthing Camera System (EBCS), to properly berth the Attached Payload passive PAS to the guide vanes and capture latch and EBCS target of the active PAS/UCCAS on the truss. After successful attachment, the SSRMS releases and the MT moves to the next task. If the Attached Payload is designed for Dexterous Robotic Support (for maintenance), the Attached Payload will interface with the SSRMS/Special Purpose Dexterous Manipulator (SPDM) using a Standard Dexterous Grasp Fixture (SDGF), a micro–conical fitting and/or bare bolt interfaces. An animated video of the transportation process can be viewed on the MAGIK WEB page, (http://tommy.jsc.nasa.gov/er/er3/magik/movies/movies_index.html).

3.4 INTERNATIONAL SPACE STATION ENVIRONMENT

The natural environment is the environment as it exists unperturbed by the presence of the ISS. The induced environment is the environment that exists as a result of the presence of the ISS. Payload developers should be aware of the potential effects the two environments can have on Attached Payloads.

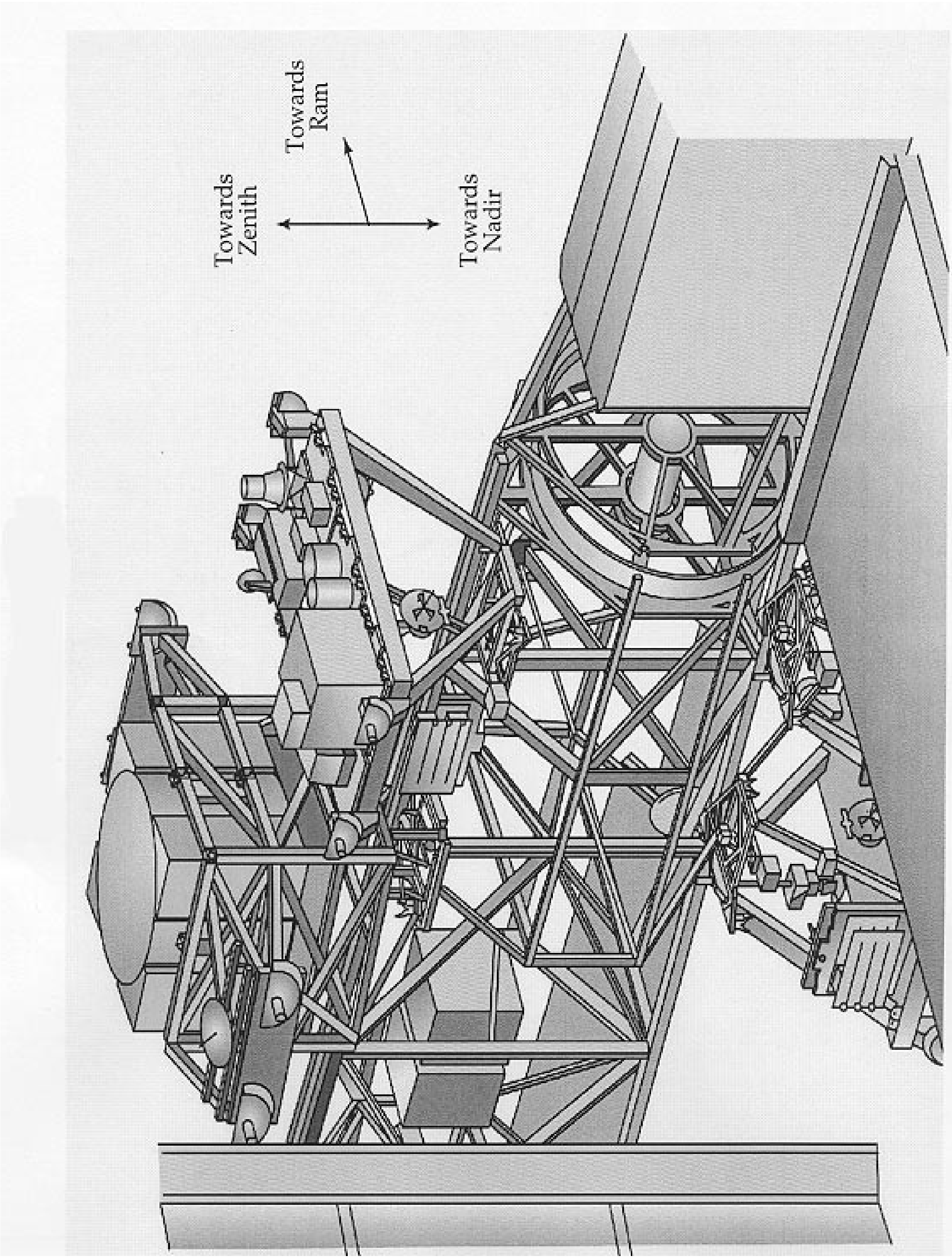


FIGURE 3.2.2–1 EXPRESS PALLET AND AMS

3.4.1 NATURAL ENVIRONMENT

The natural environment surrounding the ISS is of importance to the payload community for at least two reasons: (1) It may affect the design and operation of Attached Payloads; and (2) it may be the object of investigation for experiments conducted using the payload equipment. The objective of this description is to define the natural environment as it might affect the design and operation of payload equipment. The inclusive environments described here include:

A. Neutral Atmosphere

B. Plasma

C. Charged Particle Radiation

D. Electromagnetic Radiation (EMR)

E. Meteoroids

F. Space Debris

G. Magnetic Field

H. Thermal, Pressure, and Physical Constants

I. Gravitational Field

Note that the space debris and electromagnetic environments include elements produced by the activities of human beings: orbital debris and radio frequency radiation generated on the earth. These latter two environments are included in this discussion because they are part of the ambient environment to which the ISS and its payloads are exposed. Section 3.4.2 discusses how this natural environment interacts with the ISS to produce an induced environment surrounding and interior to the ISS. Detailed descriptions of direct interactions of orbiting elements with the earth's atmosphere are contained in SSP 30425, Space Station Program Natural Environment Definition for Design.

3.4.1.1 THE NEUTRAL ATMOSPHERE

The neutral atmosphere (i.e., thermosphere) extends from about 90–km to 500 –km altitude. It interacts with the ISS to produce drag (and torque) and modulates the flux of trapped radiation at the ISS orbital altitude.

3.4.1.2 PLASMA

Plasma is a quasi–neutral gas consisting of neutral and charged particles which exhibit collective behavior. From approximately 80–km altitude to about 1,000–km altitude, a plasma environment about the earth is designated as the ionosphere. A plasma environment extends further from the earth into a region designated as the magnetosphere and still further into the solar wind. Note that the ionosphere coexists with the thermosphere for a good part of its altitude range.

A primary interaction of plasma with a spacecraft is the accumulation of an electrical charge by the spacecraft until electrical equilibrium is reached between the spacecraft and the local plasma environment. Because electrons have greater thermal velocities than do ions at similar temperatures, a spacecraft tends to reach equilibrium potential at a few volts negative with respect to the plasma at ISS altitudes. However, active components and their associated structure (such as solar arrays) may accumulate sufficient negative potential to produce arcing to other elements of the spacecraft. Reference is made to SSP 30425, paragraph 5.0 when the ITS S3 is exposed to the natural plasma environment and to SSP 30420, Space Station EMI Radiation and Plasma Environment, paragraph 3.3 when exposed to the induced plasma environment.

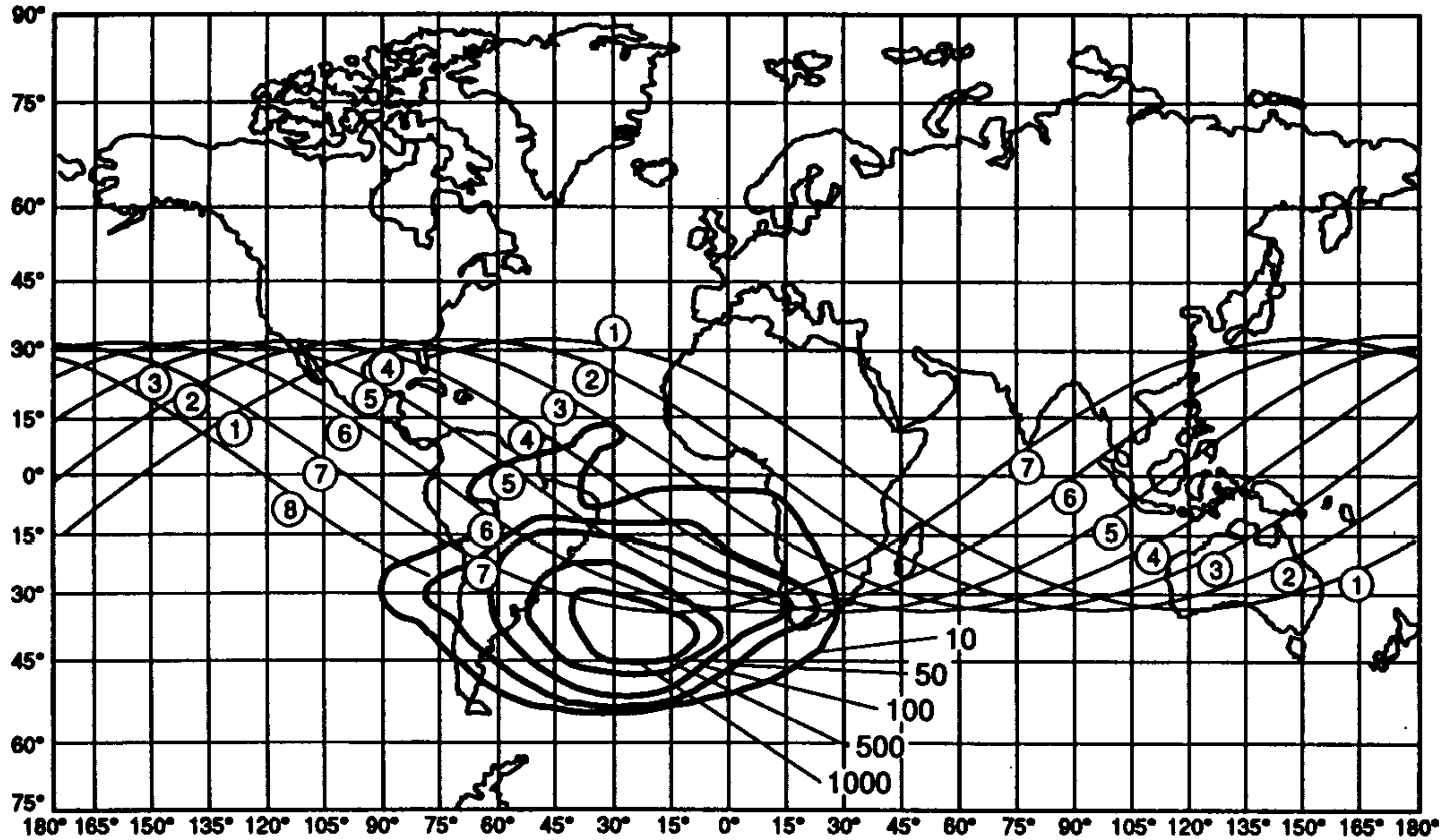
3.4.1.3 CHARGE PARTICLE RADIATION

Penetrating charged particles are produced from two sources: Magnetosphere particles are accelerated from the plasma by processes inside the magnetosphere and occur only within terrestrial space. Cosmic rays exist in interplanetary space and enter terrestrial space from outside the region. The motion of both kinds of particles is controlled by the earth’s geomagnetic field.

Charged particles that penetrate the ISS present a significant challenge to design and operation of most attached payloads. A high level of radiation will significantly affect materials, chemical processes, and living organisms. It will also affect electronics by causing soft upsets (referred to as Single Event Upsets (SEUs)), degrading performance and sometimes producing permanent damage. In addition, ionizing radiation will affect the propagation of light though optical materials by altering their optical properties.

The calculation of total flux through a given area may be quite complex. Generally, at high altitudes trapped protons contribute nearly the entire amount of total dose. Below about 300–km altitude, cosmic rays make up the largest contribution. For very thin shields of less than 0.3 g/cm^2, trapped electrons are more important than trapped protons. At high inclination orbits, solar event protons make a significant contribution to the ISS environment.

Cosmic rays produced from galactic sources typically make up less of the total dose of radiation, in rads, than trapped protons. However, these cosmic rays produce significant effects. They are responsible for SEUs, latch–up in microcircuits and, along with trapped radiation–belt protons, the nuclei induced radio–activity in most materials. Cosmic rays also induce noise by production of ionization in devices such as charged–coupled devices and by production of Cerenkov and fluorescence radiation in photomultiplier tubes. For specific design issues, the actual anticipated radiation environment must be calculated. SSP 30512, Space Station Ionizing Radiation Design Environment, and SSP 30425 provide significantly more detail and information concerning available tools for calculating the expected environment. SSP 30425 describes the general shape of the Van Allen belts following the shape of the geomagnetic field. This means that the Space Station Program Elements (SSPEs) penetrate most deeply into the belts in the region of the South Atlantic Anomaly. Because the flux is increasing with altitude in the region of 300 to 1000 kilometers, the most intense radiation is encountered in the anomaly, as shown in Figure 3.4.1.3–1.



OMNIDIRECTIONAL FLUX (PROTONS/CM^2 SEC) ENERGY > 30 MeV

FIGURE 3.4.1.3–1 PROTON FLUX DENSITIES AT AN ALTITUDE OF 296 KILOMETERS IN THE SOUTH ATLANTIC ANOMALY. THIS IS A REGION OF LOW MAGNETIC FIELD

3.4.1.4 ELECTROMAGNETIC RADIATION

Electromagnetic noise sources of significance at the ISS extend from direct current to x–ray. Only natural and remote man–made Electromagnetic Radiation (EMR) sources are considered here. The categories of noise producers are as follows:

A. Galactic

B. Solar

C. Near–Earth natural plasma

D. Man–made radio noise

The highest power densities expected to be irradiating the ISS are from the solar radiation in the ultraviolet and visible portions of the electromagnetic spectrum. The ultraviolet radiation can damage materials exposed to it. SSP 30425, paragraph 7.2, describes the degree of exposure of the payloads to the solar ultraviolet radiation environment. Other effects of EMR to be considered include radio noise and the effects of field strengths from the natural sources at the ISS. Field strengths produced from quasi–static field structures in the plasma have typical values around 25mV/m, but can be larger. These values generally occur at latitudes greater than 50°.

3.4.1.5 METEOROIDS/ORBITAL DEBRIS

The orbital environment consists of meteroids, which are natural in origin and orbital debris, which is the result of man–made material remaining in orbit. Meteoroids and orbtal debris may impact the ISS and Attached Payloads and potentially cause a threat or damage.

SSP 30425, Space Station Program Natural Environment Definition for Design, section 8.0, specifies the Meteoroid environment to which the ISS components are exposed. NASA/TP–2002–210780, The New NASA Orbital Debris Engineering Model ORDEM2000, defines the orbital debris environment.

3.4.1.6 MAGNETIC FIELD

The earth’s magnetic field, besides acting directly with the ISS to produce electric field gradients in the Station and its components, traps charged particles and deflects low–energy cosmic rays. It is also basically a dipole field. The magnetic field at altitudes up to approximately 2000 km is determined by this near–earth field, but above this altitude strong currents of charged particles within the magnetosphere cause deviations.

The earth's magnetic field is not constant and fluctuates with time (may be cyclic). There are various analytical models in existence (computer programs) to calculate trapped radiation and the field strength expected to be encountered by the ISS for a specific time.

The natural on–orbit electromagnetic field environment to which payloads will be exposed is defined in SSP 30425, section 7.0

The natural magnetic field created by the earth to which payloads are exposed in low earth orbit is defined in SSP 30425, section 9.0

3.4.1.7 THERMAL, PRESSURE, AND PHYSICAL CONSTANTS

Detailed evaluations of external environments require the use of many thermal, ambient pressure, and other physical constants. To assist in the consistent use of physical constants for detailed analyses, SSP 30425 provides listings of constants that can be used in developing models of the environment.

3.4.1.8 GRAVITATIONAL FIELD

A model of the gravitational field which takes into account the earth's non–uniform mass distributions is provided in SSP 30425 section 11.0. The model provides orbit position to an accuracy of a few hundred meters by calculating the un–normalized Legendre functions using 4 x 4 coefficients. If more accurate analyses are required, reference to a source for 36 x 36 coefficients is also provided.

3.4.2 INDUCED ENVIRONMENTS

SSP 57003, Attached Payload Interface Requirements Document, section 3.5, specifies the environmental conditions that exists as a result of the presence of the ISS and in which the attached payloads operate.

3.5 FLIGHT OPERATIONS

3.5.1 COMMAND AND CONTROL OF ATTACHED PAYLOADS

Operations of the payloads are controlled via the flight crew, mission and payload controller, and automated processes. The C&DH system supports both manual and automated control for all nominal and planned contingency conditions. Payload commands may be issued from on–board automated command blocks, the Portable Computer System (PCS), or uplinked from the ground. Procedures are automated (pre–programmed) where practical to relieve the crew workload and to preclude a need for crew activities to maintain or initiate payload functioning during normal communication outages. The payload developer may receive data from an attached payload and issue payload commands while it is in operation on–orbit. For payload developers who require near real time data from their attached payload, the onboard C&DH and the Communications and Tracking (C&T) system downlinks payload data to the Payload Operations Integration Center (POIC) first with ancillary data and then forwards the data to a payload developer's facility. In addition, the C&DH extracts previously specified ancillary data necessary for payload developer processing of payload data from the core operations data stream. The C&DH system forwards these data through the C&T system for near real time downlink to the payload developer's facility. The mode of data transmission is dependent upon the nature of the payload and the payload developer's data requirements. Payload developer's may receive data in near real time, at prescheduled times and as playback anytime up to one year after the receipt of the payload or ancillary data.

3.5.2 CONTINGENCY OPERATIONS

While an attached payload is on orbit, the payload developer performs remote operations and oversees any actions taken by the crew with regard to the attached payload. Requirements imposed on external experiment/payload design include the use of EVR tasks to accomplish regular maintenance and operational functions and preclude the use of planned EVAs for these activities. However, design features must accommodate EVAs in the event that contingency events are to be addressed with EVA tasks.

4.0 SYSTEM DESCRIPTIONS, INTERFACES, AND PAYLOAD ACCOMMODATIONS

This section provides a description of subsystems, interfaces, and payload accommodations for transportation and on–orbit as related to Attached Payloads and Unpressurized Cargo Carriers (UCCs) at the S3/P3 locations. Descriptions are included to familiarize payload developers with available accommodations and assist with payload design. Specific payload design requirements are included in SSP 57003. Section 4.0 of this handbook is organized by the types of interfaces a payload may have with the ISS.

4.1 STRUCTURES AND MECHANISMS

4.1.1 STRUCTURES

The function of a structure is to transfer loads and provide support for the various systems. Loads are the Newtonian (mechanical), pressure, and thermally induced forces applied to structural elements. The structures on ISS are made primarily of aluminum alloy. There are two main types of structures on ISS: pressurized elements and truss assemblies. Truss assemblies provide the structural backbone of the Station and attach points for exposed payloads. Truss assemblies also contain electrical utility lines, the mobile transporter rails, and mechanical systems such as joints and mechanisms.

4.1.1.1 INTEGRATED TRUSS STRUCTURE

The ITS is made up of 11 individual pieces (i.e., segments). At full assembly the truss reaches 100 meters (m.) in length. The segments are labeled in accordance with their location. Within each truss segment, utility routing corridors are internally provided to accommodate external payloads and maintenance equipment. Each attach site location provides standard mechanical attachments and a connector interface panel for access to Station–provided utilities. Single Attached Payloads or Unpressurized Cargo Carriers (UCCs) mount to each truss attach site via a PAS. Attached Payload/UCC structures connect to utilities through an Umbilical Mechanism Assembly (UMA).

4.1.1.2 MOBILE SERVICING SYSTEM

The Attached Payload to MSS interface provides structural support for the Attached Payload while attached to the Mobile Base System Common Attach System (MCAS). The physical interface (mechanical, structural, thermal and environmental) plane is defined at the active half of the MCAS and the passive half of the Attached Payload. The utility interface plane (power and data) is defined at the MCAS active UMA connector and the Attached Payload passive UMA connector. Access to the power and data resources is available while the MSS is parked and utilizing a truss utility port. There are no video interfaces between the MCAS and the Attached Payload. The mechanical interface between the Attached Payload and the MCAS is physically identical to the interface at the PAS sites. SSP 42004, Mobile Servicing System to

User (generic) Interface Control Document, provides the interface definition of the Attached Payload to the MSS.

4.1.1.3 INTEGRATED TRUSS SEGMENTS S3 AND P3

The physical interface between the ISS and the Attached Payloads occurs at a PAS or UCCAS site. The four PAS sites located on the ITS S3 have been designated as primary Attached Payload sites. The two UCCAS sites located on the ITS P3 will serve as auxiliary Attached Payload sites to be used on an as available basis. The ITS design is controlled by SP–M–235, Specification to Prime Item Development Specification for Integrated Truss Element P3, and SP–M–229, Addendum Specification to Prime Item Development Specification for Integrated Truss Element P3 for Integrated Truss Element P3 for Integrated Truss Segment ITS S3. All six interfaces support the transfer of structural loads, power and data. All six sites are configured for support of multiple cycles of robotically assisted Attached Payload and Unpressurized Cargo Carrier installation and removal. All six sites are also configured for remotely actuated connection and disconnection of Attached Payloads and Unpressurized Cargo Carriers to and from the ISS resources and services. PAS sites are shown in Figure 4.1.1.3–1. UCCAS sites are shown in Figure 4.1.1.3–2.

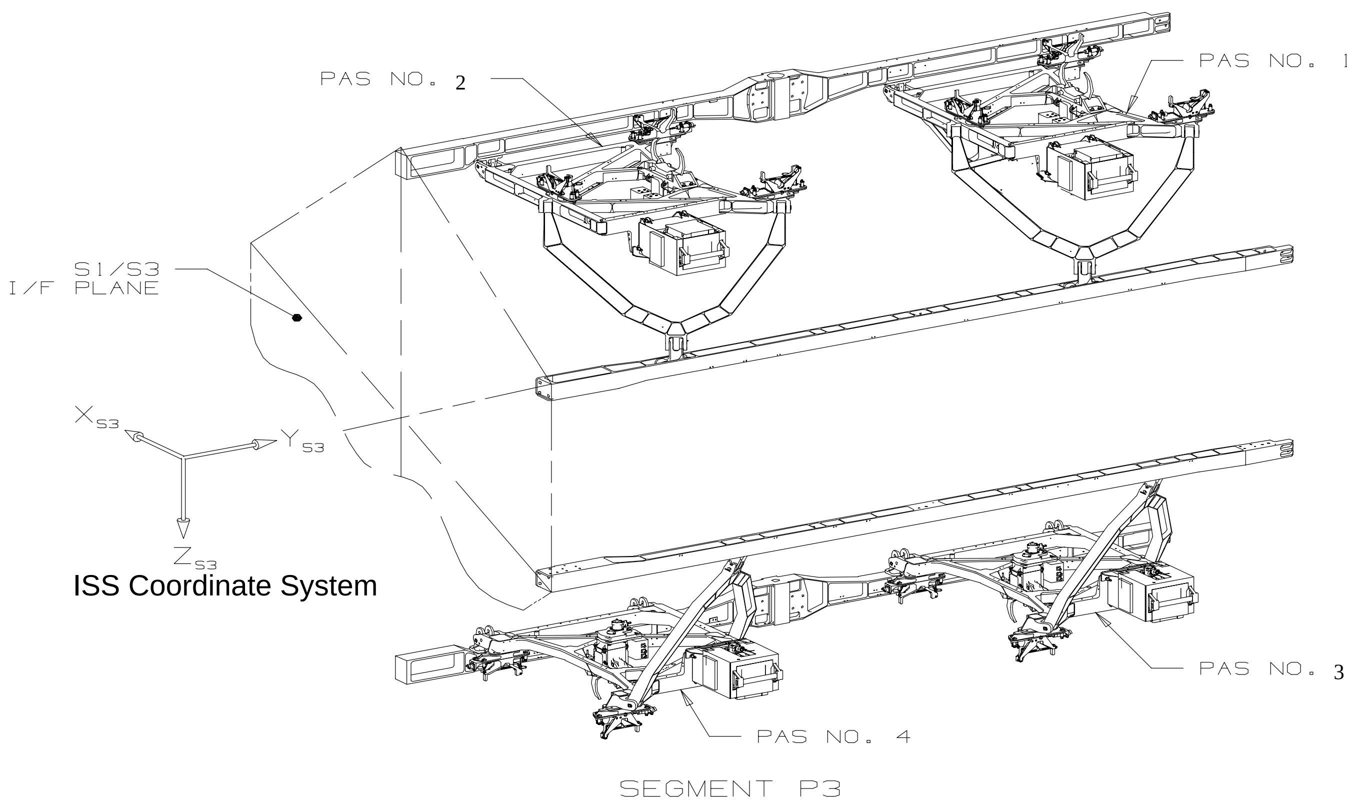


FIGURE 4.1.1.3–1 INTEGRATED TRUSS SEGMENT S3 PAYLOAD ATTACH SYSTEM SITES

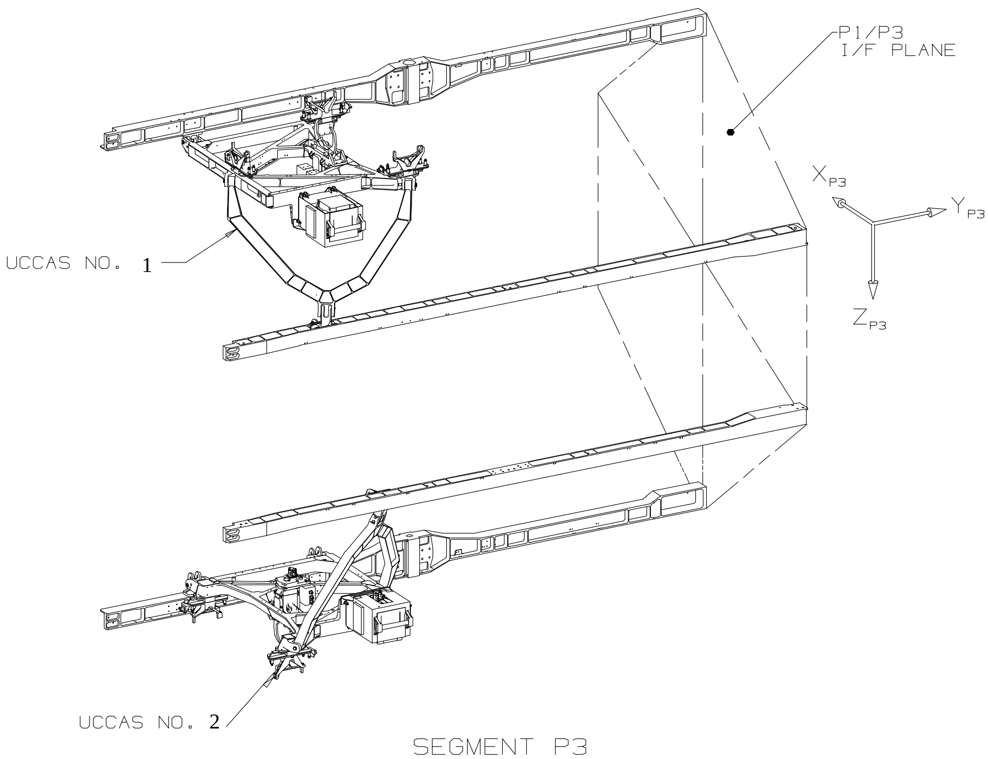


FIGURE 4.1.1.3–2 INTEGRATED TRUSS SEGMENT P3 UNPRESSURIZED CARGO CARRIER ATTACH SYSTEM SITES

4.1.2 MECHANISMS

The function of the ITS mechanisms is to structurally attach and stabilize payloads on the attach sites.

4.1.2.1 ACTIVE PAYLOAD ATTACH SYSTEM

The Payload Attach System (PAS) is that portion of ITS S3 that has direct physical contact with the Attached Payload and is provided by the ISS. The active PAS design is controlled by SP–M–602, Configuration Item Specification for the Payload Attach System. The primary components of the active PAS interface are an active Umbilical Mechanism Assembly (UMA), a Capture Latch Assembly (CLA), three (3) guide vanes and an External Berthing Camera System (EBCS) target to support robotic Attached Payload installation and berthing. Figure 4.1.2.1–1 illustrates the active PAS and Figure 4.1.2.1–2 shows the active PAS interface dimensions (in inches) and defines the location of the local coordinate system origin for the PAS.

The Unpressurized Cargo Carrier Attach System (UCCAS) is that portion of ITS P3 that has direct physical contact with the Unpressurized Cargo Carriers and Attached Payloads and is provided by the ISS. The UCCAS is controlled by SP–M–603, Configuration Item for the Unpressurized Cargo Carrier Attach System. A UCCAS unit is similar to the PAS and can be represented by the same figures as the PAS since the interface to the payload is identical. The only difference between the two units is that the UCCAS provides an additional fault tolerance by adding a second Integrated Motor Assembly (IMCA) to both its Capture Latch Assembly (CLA) and Umbilical Mechanism Assembly (UMA).

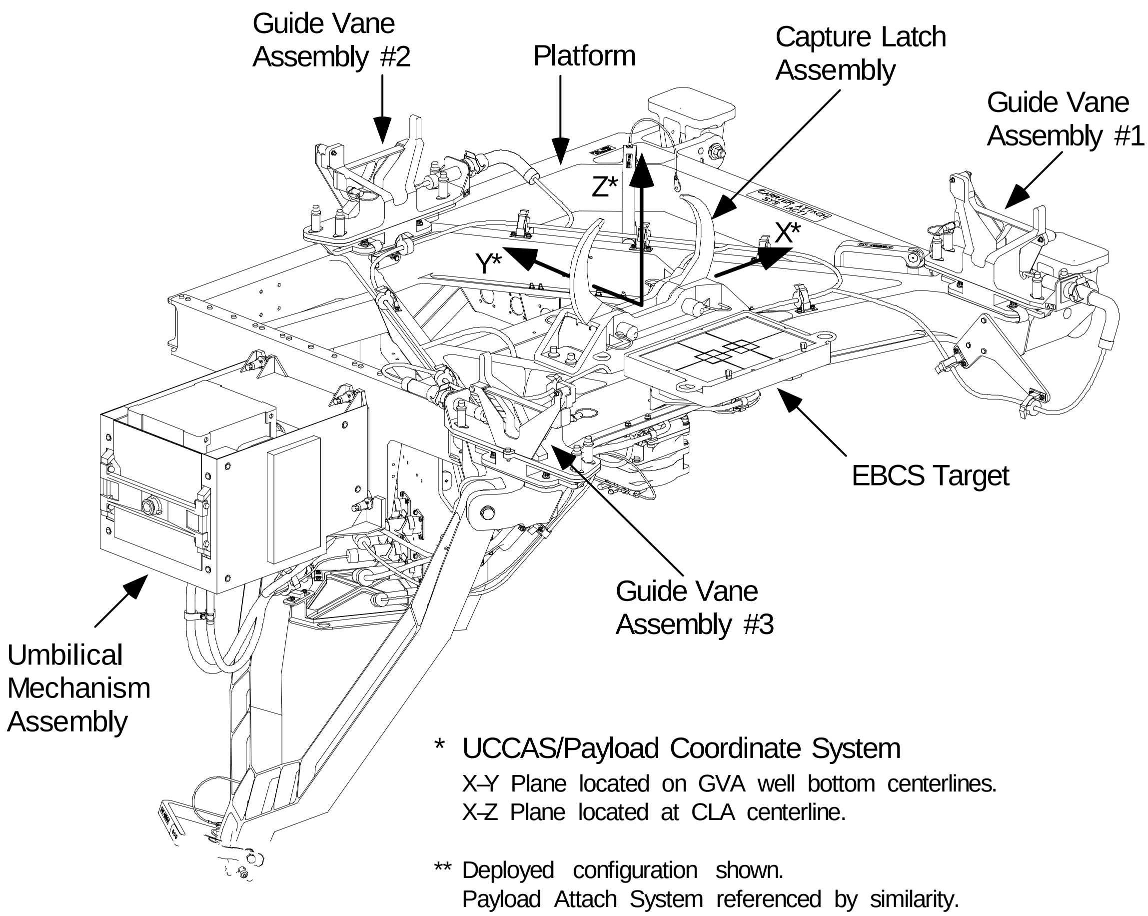


FIGURE 4.1.2.1–1 ACTIVE PAYLOAD ATTACH SYSTEM

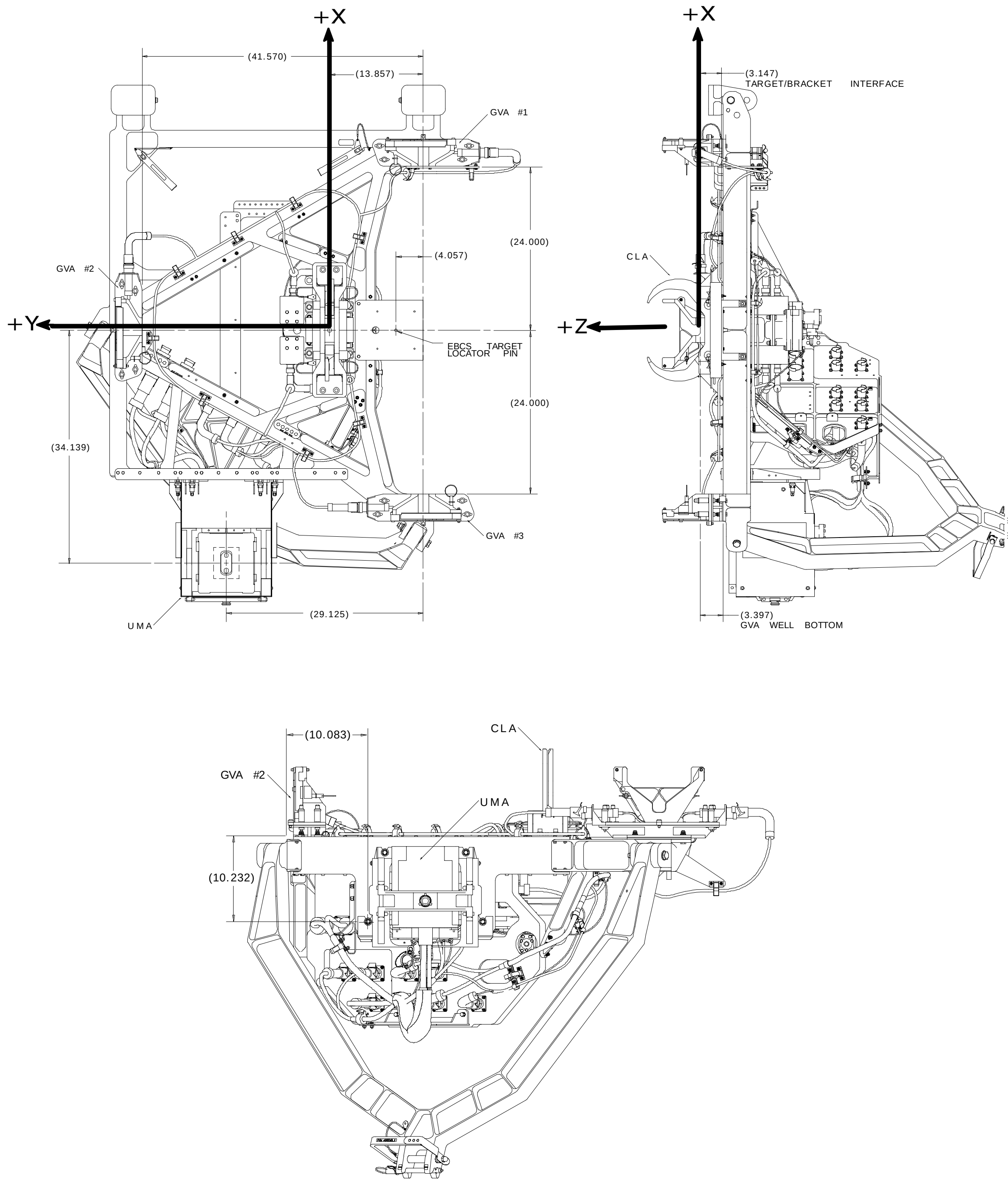
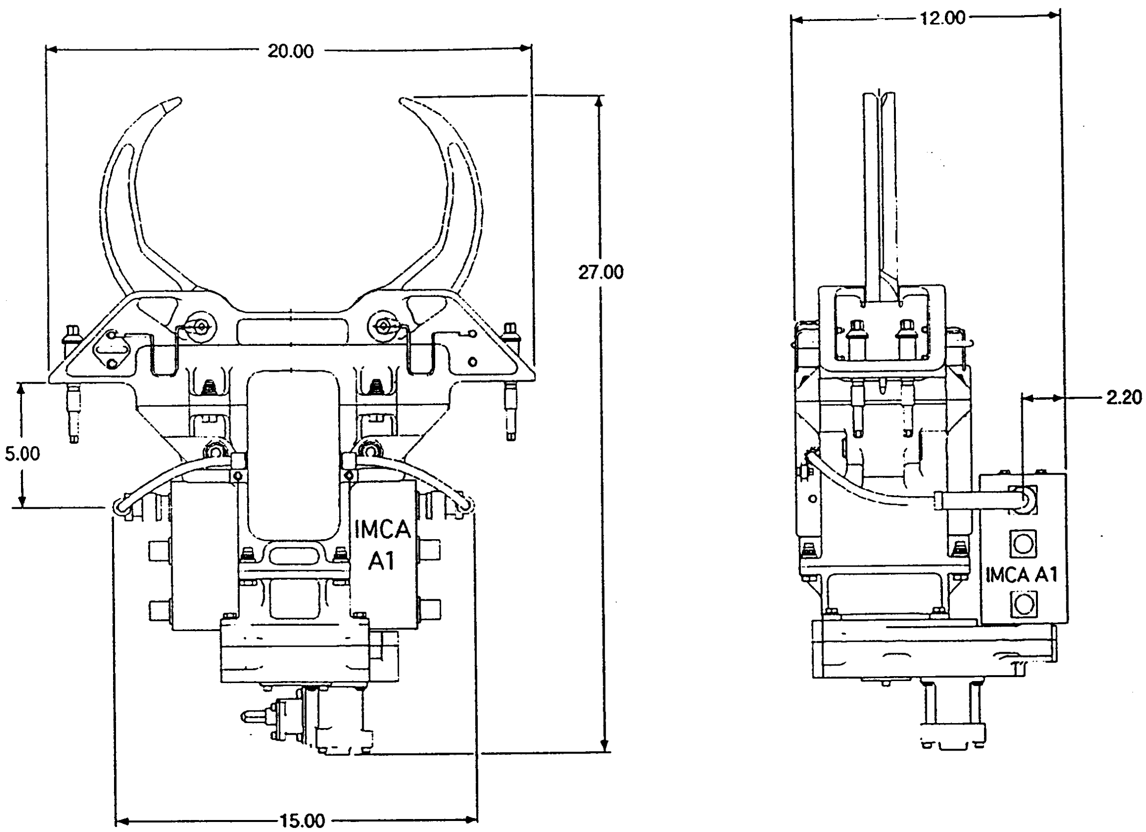


FIGURE 4.1.2.1–2 PAYLOAD ATTACH SYSTEM STRUCTURAL DIAGRAM

4.1.2.1.1 CAPTURE LATCH ASSEMBLY

Each active PAS includes one CLA. The CLA is a remotely actuated mechanism supporting capture, berthing and structural integration of Attached Payloads to the attach system support frame. Each CLA consists of a pair of latch jaws that are driven open and closed by a standard DC Integrated Motor Control Assembly (IMCA). The CLA operates in conjunction with the three guide vanes located on the PAS/UCCAS. The guide vanes maintain proper alignment of the guide pins as the Attached Payload is brought into final position. A CLA is shown in Figure 4.1.2.1.1–1. The operational sequence for capture of the Attached Payload/UCC by the PAS/UCCAS is shown in Figures 4.1.2.1.1–2, 1 through 10. The drawings and dimensions in Figures 4.1.2.1.1–2, 1 through 10, are for reference only.



NOTE:
- ALL DIMENSIONS ARE FOR REFERENCE ONLY
- REFERENCE SSP 57004 FOR INTERFACE DIMENSIONS

FIGURE 4.1.2.1.1–1 CAPTURE LATCH ASSEMBLY

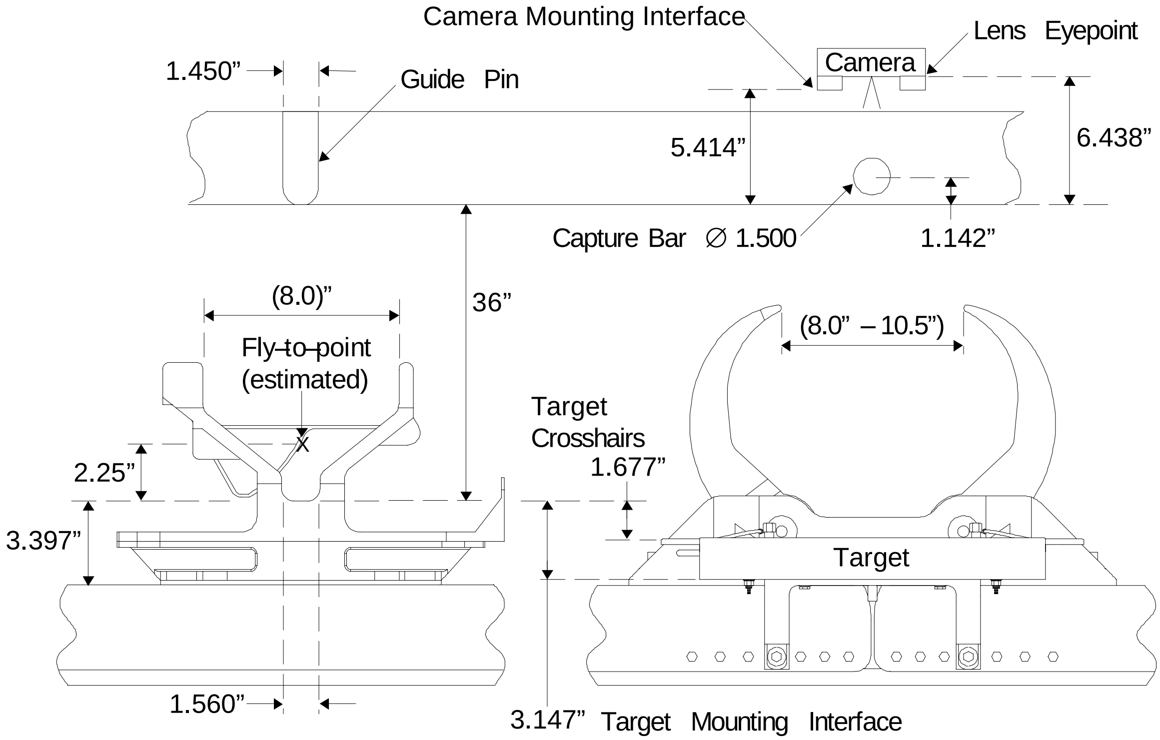


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – PRE INSTALL POSITION (1 OF 10)

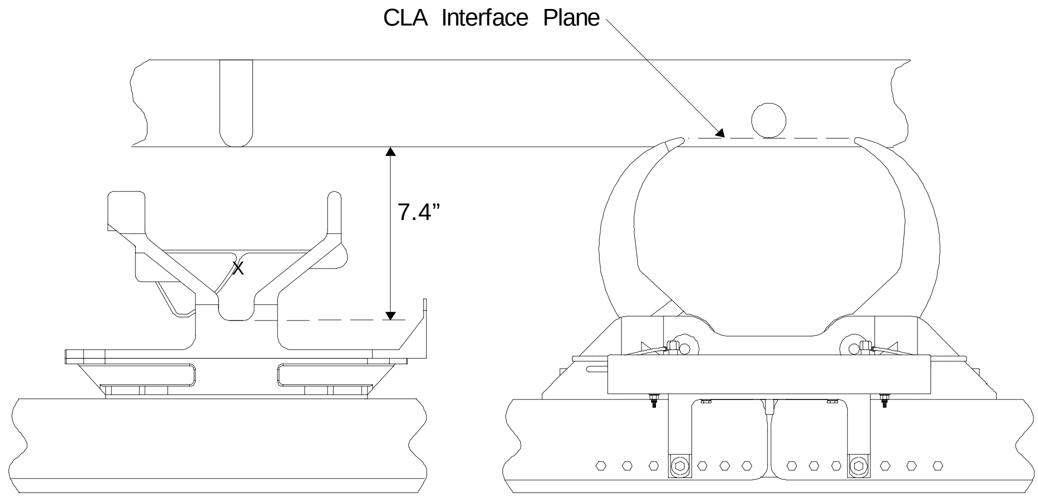


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – CLA HARDWARE INTERFACE PLANE (2 OF 10)

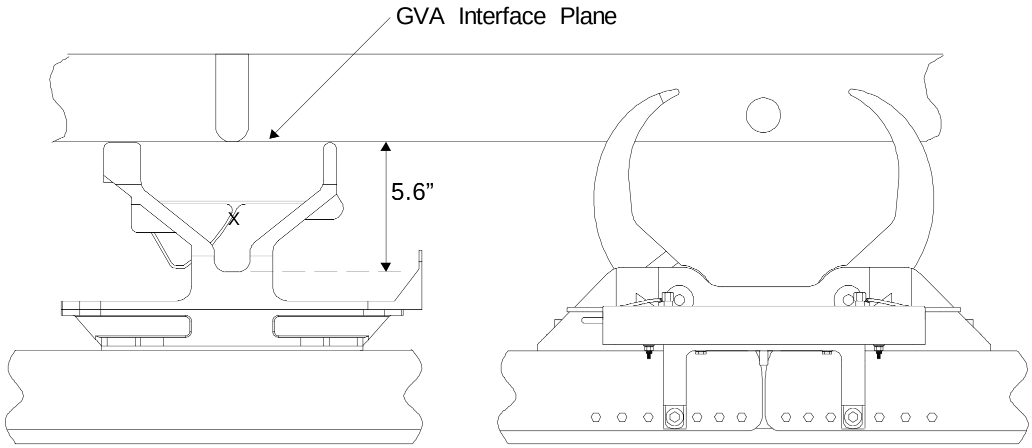


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – GVA HARDWARE INTERFACE PLANE (3 OF 10)

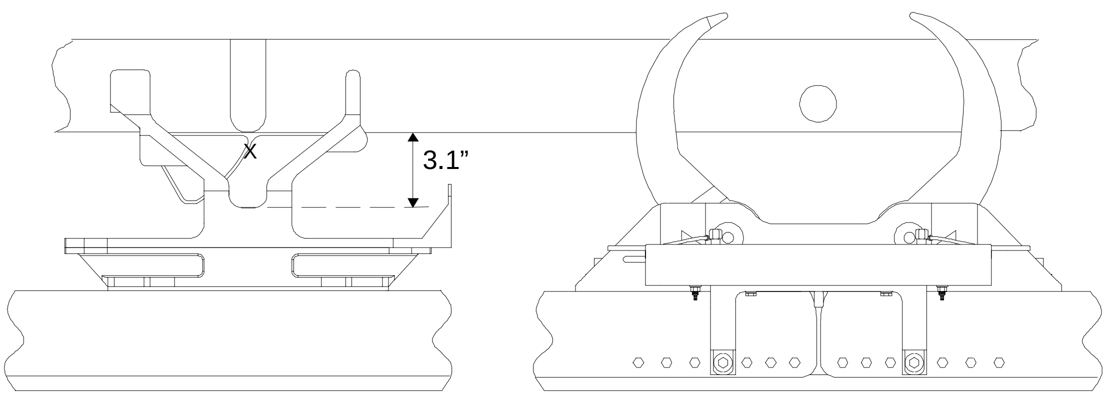


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – RTL SENSOR GATE CONTACT (4 OF 10)

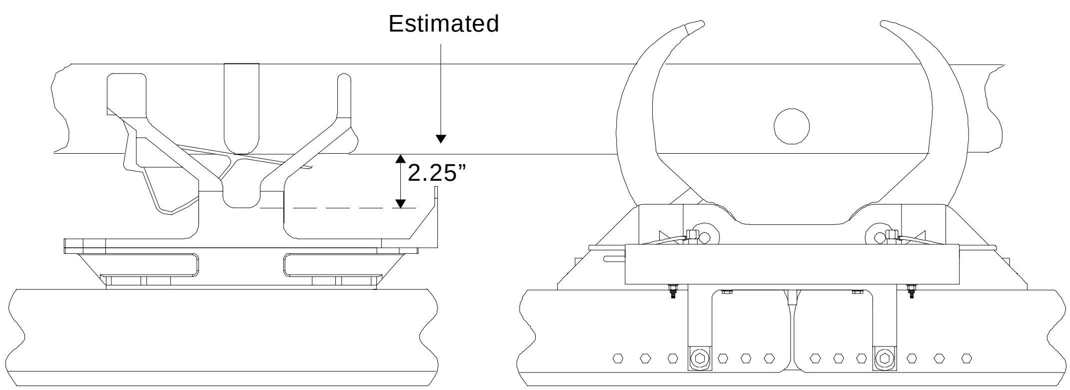


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – FLY TO POINT (RTL INDICATION) (5 OF 10)

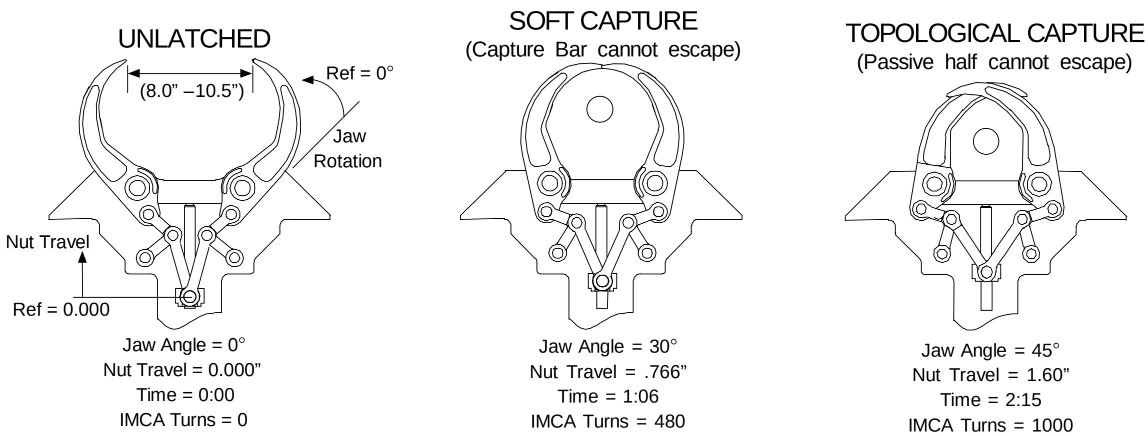


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – LATCHING PHASE I (6 OF 10)

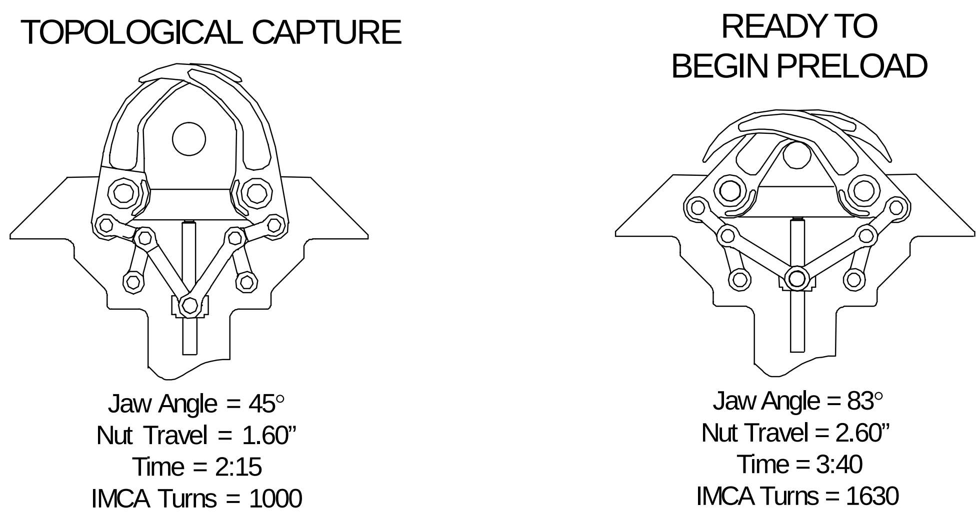


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – LATCHING PHASE II (7 OF 10)

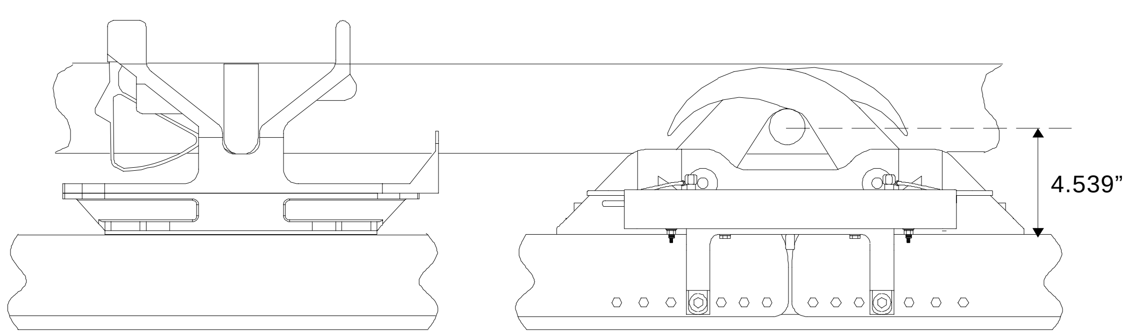


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – FULLY SEATED (NO PRELOAD) (8 OF 10)

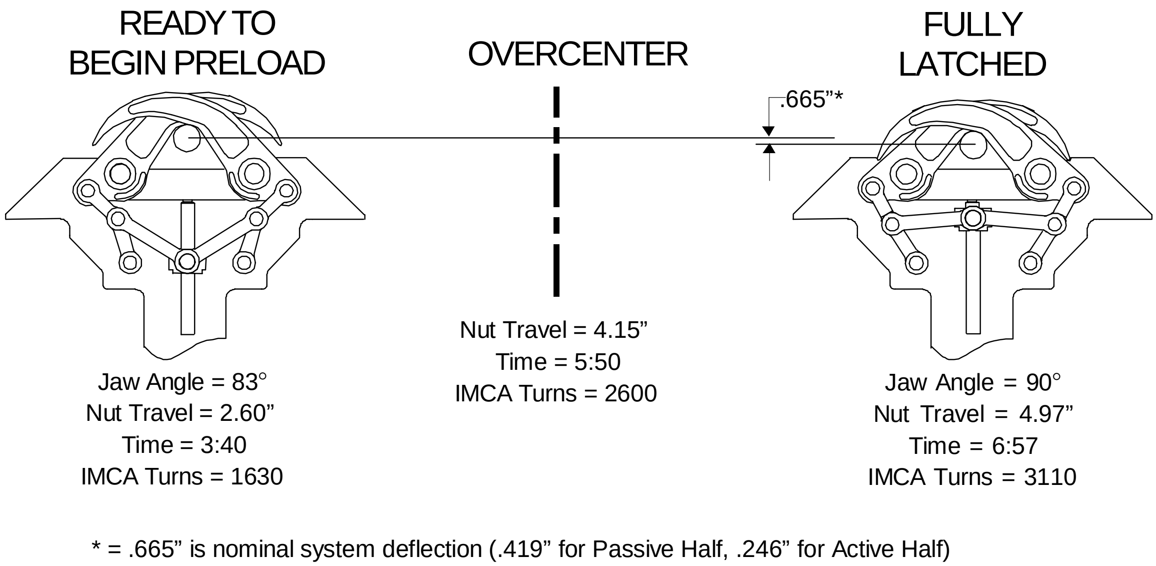


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – LATCHING PHASE III (9 OF 10)

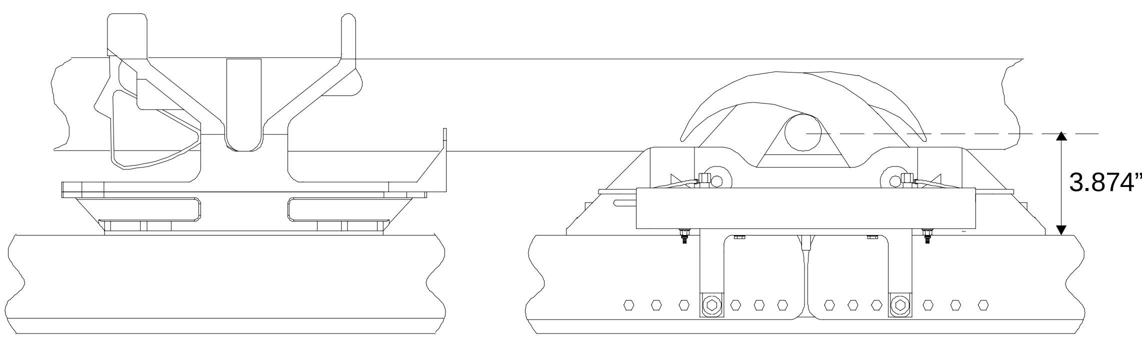


FIGURE 4.1.2.1.1–2 OPERATIONAL SEQUENCE – FULLY LOADED (10 OF 10)

4.1.2.1.2 GUIDE VANES

The active PAS has three guide vanes that interface with the three guide pins on the Attached Payload passive PAS. The guide vanes and pins guide the Attached Payload as it is being drawn into final position by the CLA. The guide vanes include Ready–To–Latch (RTL) indicators that provide information back to the SSRMS operators that the Attached Payload is properly positioned within the CLA capture envelope prior to CLA activation. Figure 4.1.2.1.2–1 shows the guide vane design.

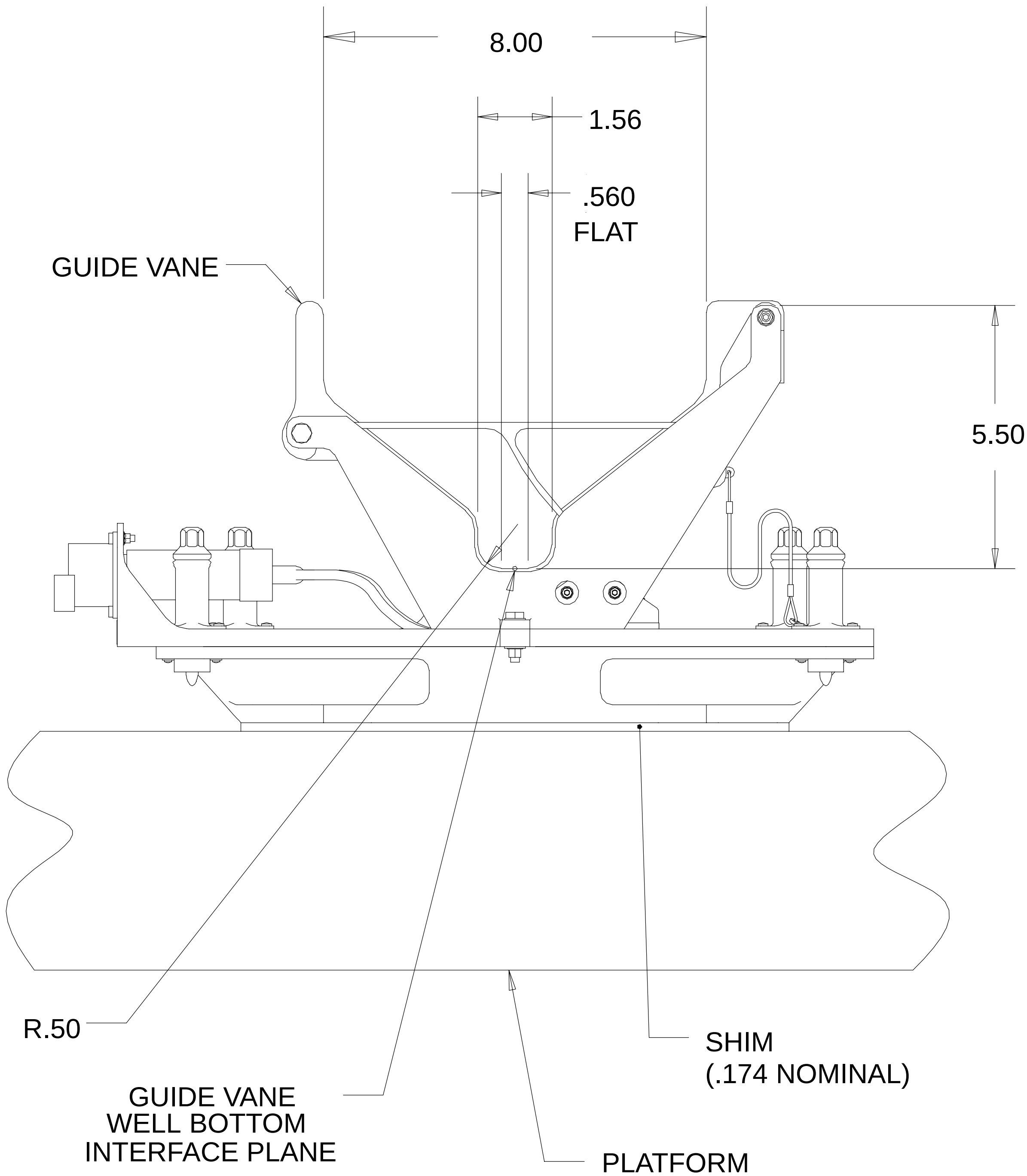


FIGURE 4.1.2.1.2–1 GUIDE VANES

4.1.2.1.3 ACTIVE UMBILICAL MECHANISM ASSEMBLY

Each active PAS includes one active UMA. The active UMA is a remotely actuated mechanism providing connection and disconnection of the Attached Payload to the ISS power and data systems. The active UMA dimensions are shown in Figure 4.1.2.1.3–1.

4.1.2.1.4 EBCS TARGET

Each active PAS also includes an External Berthing Camera System (EBCS) target to assist with Attached Payload/UCC berthing. The EBCS target is shown as part of the active PAS in Figures 4.1.2.1–1 and 4.1.2.1–2. Figure 4.1.2.1.4–1 illustrates the EBCS target.

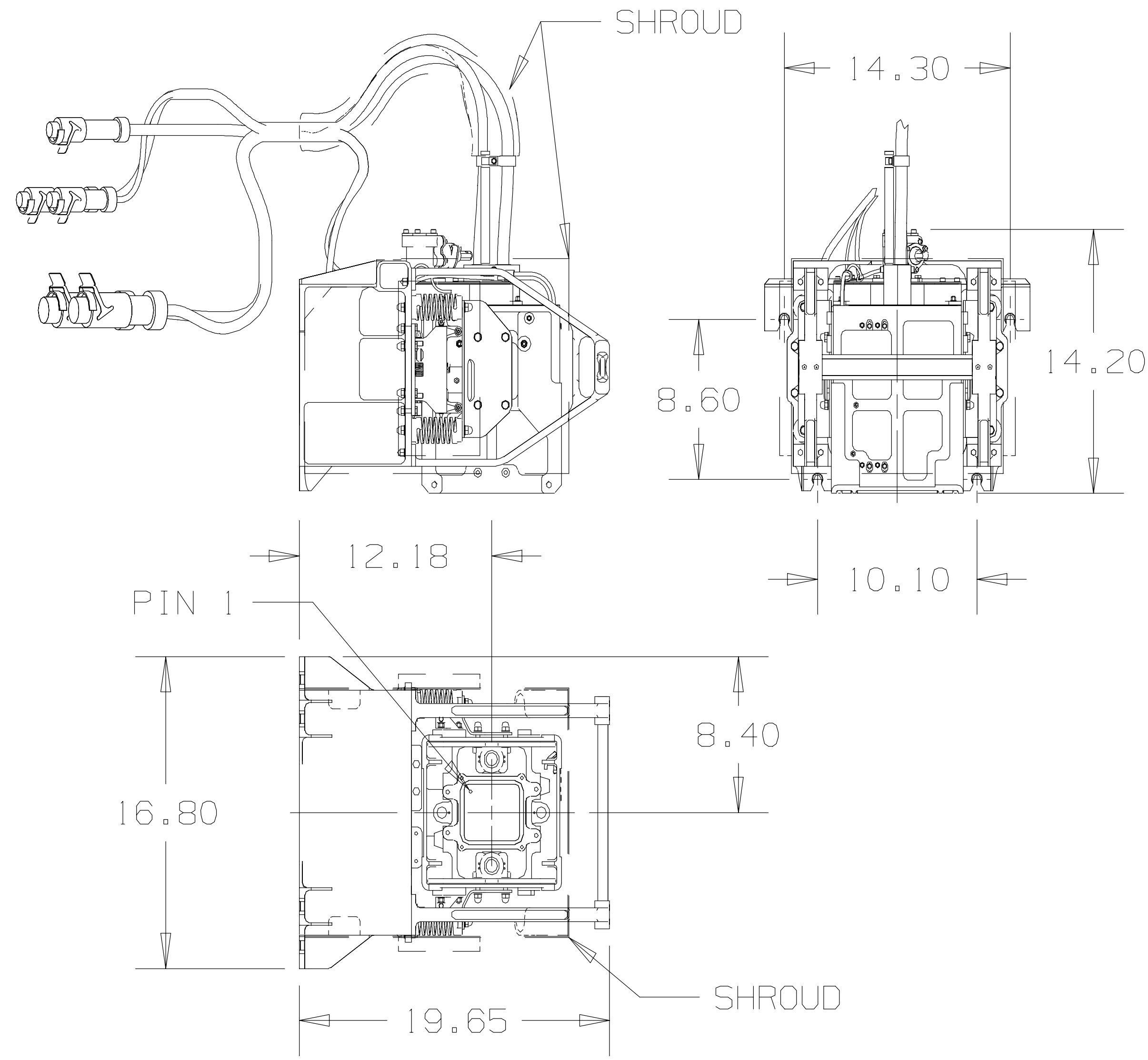
The fully assembled EBCS target is approximately 10” x 14” and weighs approximately 11.2 pounds. The target has two sets of markings so that the EBCS primary and redundant cameras each look directly at a set of markings. The EBCS Target Assembly consists of two subassemblies, the Mounting Frame Assembly and the Cue Plate Assembly. Upon installation, the EBCS target is aligned pre–flight to within an allotted error budget. The Mounting Frame Assembly is permanently attached to the active PAS. The Cue Plate Assembly is designed for EVA replacement should the target be damaged for any reason. The Mounting Frame Assembly is designed such that the replacement Cue Plate Assembly, when installed, would be aligned to within the original error budget with no adjustment required. The EBCS target is designed with a five year lifetime. Based on capture latch cycles (also a limited life item), both the capture latch and EBCS target would be changed out at the same time.

4.1.2.2 PASSIVE PAYLOAD ATTACH SYSTEM

Attached Payloads interfacing directly to the PAS/UCCAS will be required to provide interfaces meeting the ISS specifications. For the purpose of this PAH, the Attached Payload portion of the interface will be termed the passive PAS. As a minimum, each passive PAS must include an EVA releasable and removable capture bar assembly, three guide pins, a support frame to maintain the proper component positioning and to react and transfer loads and an EBCS avionics package (camera) to support SSRMS berthing operations. The passive UMA design requires a mounting bracket to attach the passive UMA to the payload structure. A representation of a passive PAS is shown in Figure 4.1.2.2–1.

4.1.2.2.1 EXTRAVEHICULAR ACTIVITY RELEASABLE AND REMOVABLE CAPTURE BAR

The Attached Payload design will include an EVA releasable and removable capture bar to interface with the PAS CLA. The design, location and tolerances for this capture bar are in accordance with SSP 57004, Figure 3.1.2.2–1. This bar is required to be releasable to ensure sufficient failure tolerance during the payload berthing and latching operation.



NOTE:
- ALL DIMENSIONS ARE FOR REFERENCE ONLY
- REFERENCE SSP 57004 FOR INTERFACE DIMENSIONS

FIGURE 4.1.2.1.3–1 ACTIVE UMBILICAL MECHANISM ASSEMBLY DIMENSIONS

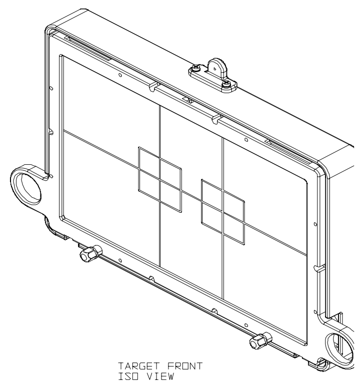


FIGURE 4.1.2.1.4–1 EBCS TARGET ASSEMBLY

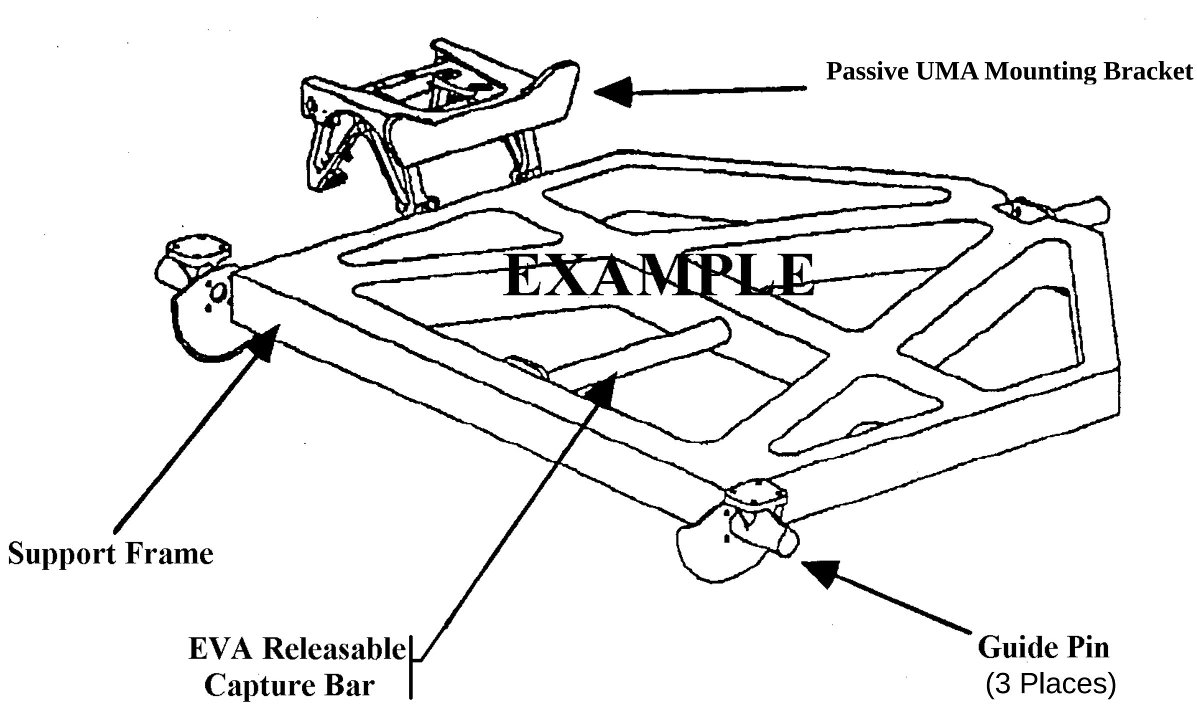


FIGURE 4.1.2.2–1 PASSIVE PAYLOAD ATTACH SYSTEM

4.1.2.2.2 GUIDE PIN DESIGN

The Attached Payload has three guide pins integral to the passive PAS to interface with the active PAS/UCCAS guide vanes. The guide pins assist the berthing operation by guiding the payload into the guide vanes. They also serve to provide the structural footprint for the payload and provide an electrical bonding surface at the flats on the underside of each pin.

4.1.2.2.3 PASSIVE UMBILICAL MECHANISM ASSEMBLY

The passive UMAs provide a structural/mechanical interface to the active PAS UMA to allow physical integration of the Attached Payload to the PAS/UCCAS. The passive UMA provides the interface for the payload power and data connections and meets the requirements of SSP 57003. The passive UMA is accessible for manual EVA backup operation in accordance with SSP 50005, paragraph 12.3. The passive UMA must be procured from NASA or a NASA–approved supplier. Representations of a passive and an active UMA, provided for illustrative purposes only, are shown in Figures 4.1.2.2.3–1 and 4.1.2.2.3–2.

4.1.2.2.4 EBCS AVIONICS PACKAGE

Attached Payloads interfacing with the PAS/UCCAS sites will be required to install an EBCS avionics package (camera assembly) to support SSRMS berthing operations. The EBCS Avionics/Camera Assembly is illustrated in Figure 4.1.2.2.4–1.

The EBCS avionics package, provided by NASA, will be integrated onto the payload and will interface with the SSRMS via the Power and Video Grapple Fixture (PVGF) for power and video connection to the ISS. The cues needed by the SSRMS operator for payload berthing are provided in a real time video image taken from the EBCS camera(s) on the payload when the payload is within 3 feet of the PAS interface plane for berthing.

The EBCS Avionics/Camera Assembly includes alignment mechanisms, two redundant camera systems – each with an LED ring to illuminate the camera’s field of view, video signal conditioning avionics and power conditioning components. Operational power is provided to the avionics package by the SSRMS via the PVGF connector interfaces. After berthing operations, the avionics package receives keep–alive heater power provided by the payload.

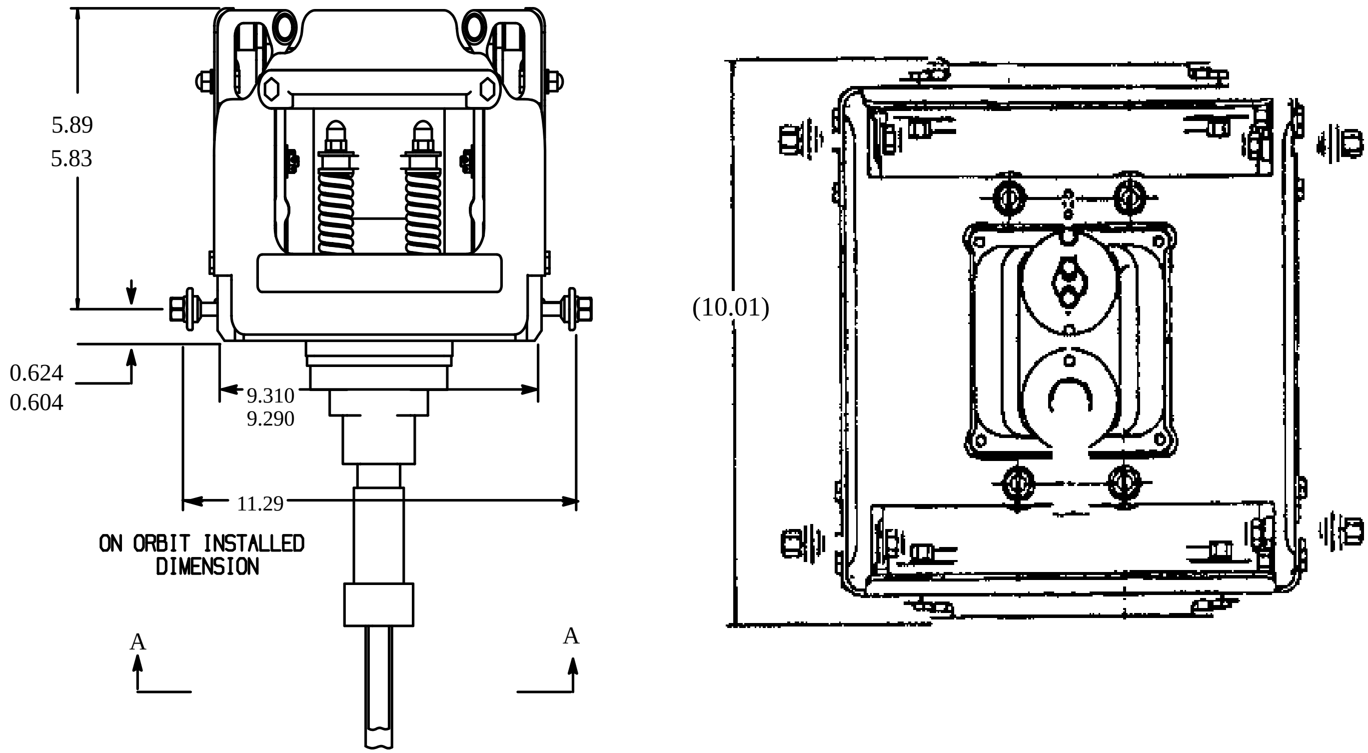


FIGURE 4.1.2.2.3–1 PASSIVE UMBILICAL MECHANISM ASSEMBLY

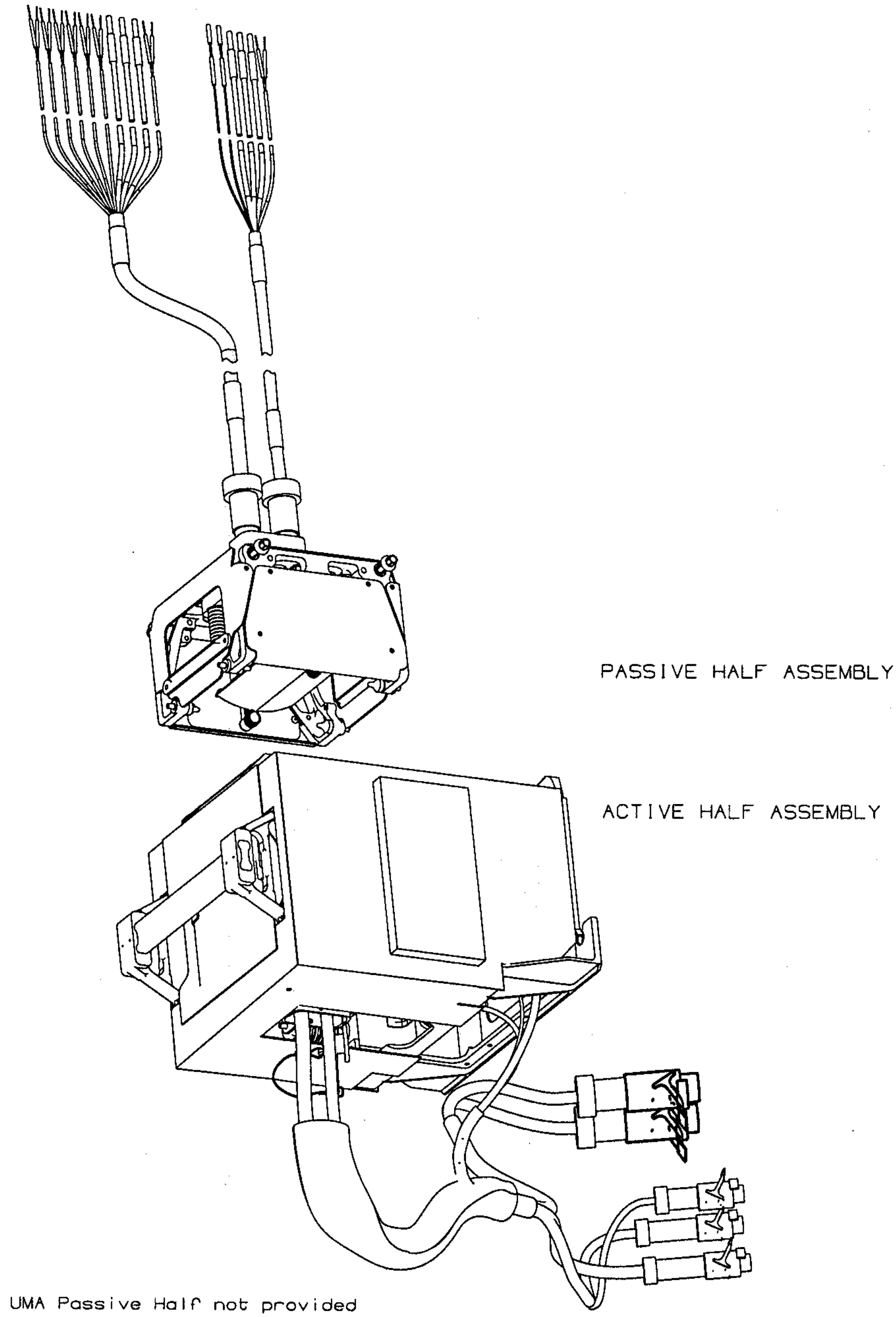


FIGURE 4.1.2.2.3–2 UMBILICAL MECHANISM ASSEMBLY

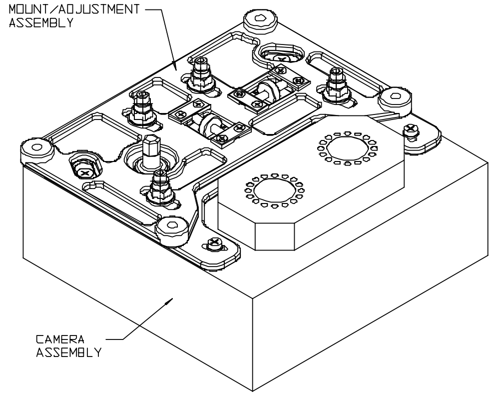


FIGURE 4.1.2.2.4–1 EBCS AVIONICS/CAMERA ASSEMBLY

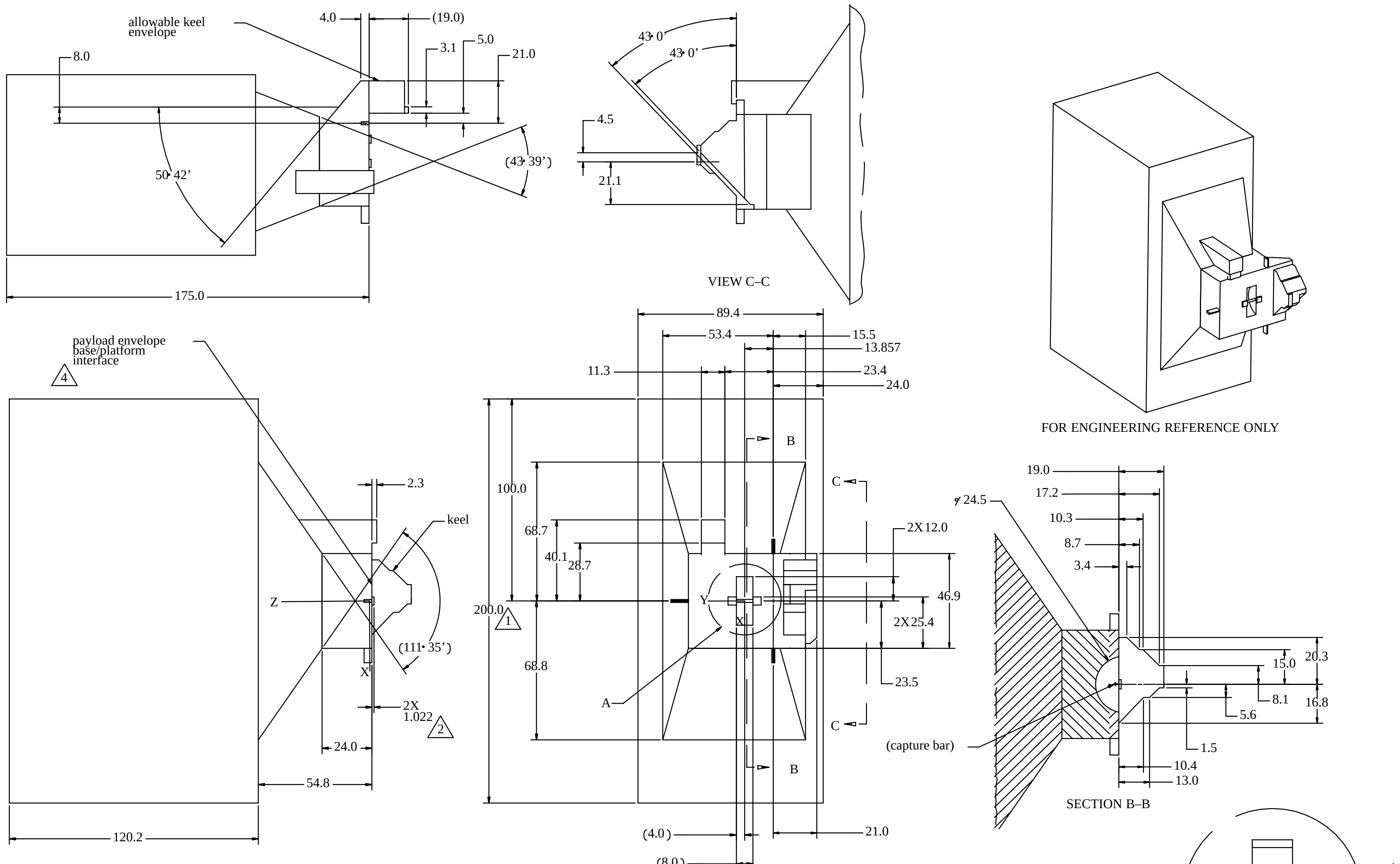
4.1.3 PHYSICAL ENVELOPE

4.1.3.1 ATTACHED PAYLOAD PHYSICAL ENVELOPE

The Attached Payload is to be designed to ensure that its envelope (i.e., transportation carrier and experiments) is in accordance with the orbiter cargo bay requirements specified in NSTS 21000–IDD–ISS, Shuttle Orbiter Interface Definition Document for International Space Station, paragraph 3.3.1 and section 4.0.

4.1.3.2 ATTACHED PAYLOAD ON–ORBIT OPERATIONAL ENVELOPE

The Attached Payload on–orbit operational envelope is not to exceed the maximum allowable operational envelope as shown in Figure 4.1.3.2–1 (SSP 57003 Figure 3.1.3.1.1.1–1 contains actual requirement).



1 REFER TO NSTS 21000 FOR SHUTTLE PAYLOAD BAY ENVELOPES.

2 THIS DIMENSION IS ALLOWED TO INCREASE TO 1.072 INCHES DURING CONTINGENCY EVA CAPTURE BAR RELEASE.

3 ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

4 REFER TO SSP 57004, FIGURE 3.1.2.2–1 FOR CRITICAL INTERFACE DIMENSIONS. SSP 57004, FIGURE 3.1.2.2–1 TAKES PRECEDENCE IN THE EVENT OF CONFLICTING DIMENSIONS.

FIGURE 4.1.3.2–1 ATTACHED PAYLOAD ON–ORBIT OPERATIONAL ENVELOPE

4.1.4 LOADS

During the transportation phase each payload will be subjected to various structural loads. These include quasi–static random vibration, and acoustic loads. Load cases to be examined include Launch and Landing/Emergency Landing Quasi–Static Loads (QSL) and Random Vibration Loads (RVL) and EVR/EVA induced on–orbit loads. Thermal effects are especially important in the on–orbit configuration. The effects of thermally induced loads from differential expansion/contraction must be combined with induced static and dynamic loads in evaluating structural integrity. Specific loads are defined in SSP 57003, paragraph 3.1.1.2.3. Instructions and requirements for application of the loads are defined in SSP 52005.

4.1.5 MASS PROPERTIES AND CENTER OF GRAVITY

For Attached Payloads between the masses of 3000 lbs and 19000 lbs the allowable center of gravity offsets shall be as follows:

A. 3000 lbs: X +/– 32 inches, Y +/– 32 inches, Z between 0 and +100 inches

B. 19,000 lbs: X +/– 32 inches, Y +/– 32 inches, Z between 0 and + 66 inches.

All dimensions are with respect to the PAS local coordinate system as defined in Figure 3.1.3.1.2.1–1. It is acceptable to linearly interpolate between the maximum and minimum payload weights and CG positions.

4.1.5.1 ATTACHED PAYLOAD COORDINATE SYSTEM

The Attached Payload will use the coordinate system defined in SSP 30219, Space Station Coordinate System. SSP 57004, paragraph 3.1.4.1 contains the S3 and P3 coordinates for the PAS/UCCAS local coordinate system origin locations.

4.2 MICROGRAVITY

The ISS will provide the proper acceleration performance environmental characteristics for microgravity experiments, as described in the paragraphs below. The requirements for limits on Attached Payload quasi–steady accelerations to assist in meeting this environment and vibratory/transient accelerations are described in SSP 57003, paragraph 3.1.3.2.6.

4.2.1 MICROGRAVITY ENVIRONMENT FOR PAYLOADS

The ISS is to provide a microgravity environment interspersed with maintenance and other operations. The plan for conducting operations is based upon rendezvous and reboost periods, roughly scheduled at 90 day increments as shown in Figure 4.2.1–1, Timeline of Events for Assessment of Microgravity Performances. After a rendezvous and resupply at relatively low

Earth orbit, the ISS will reboost to a higher orbit and coast, subject to the low orbit exoatmospheric drag conditions which prevail. The coast period nominally consists of two 30 day microgravity periods, separated by a period of maintenance. Microgravity periods are to provide a microgravity environment to a minimum of 50% of payload racks for at least 180 days per year including at least two continuous 30 day periods per year. Quasi–steady, vibratory and transient requirements are to be met during the microgravity periods. These microgravity periods also form a basis for all payload operations since power and thermal capabilities are defined for payloads only during these time intervals.

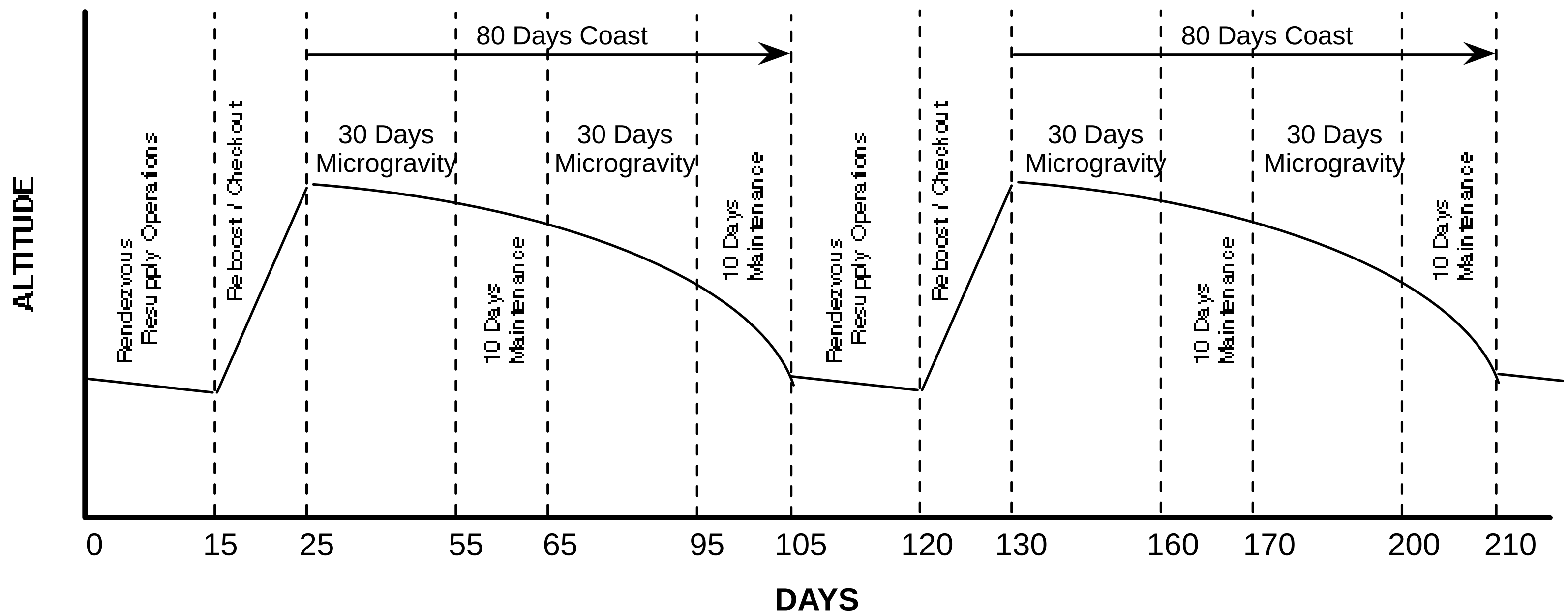


FIGURE 4.2.1–1 TIMELINE OF EVENTS FOR ASSESSMENT OF MICROGRAVITY PERFORMANCES

4.2.1.1 QUASI–STEADY ACCELERATION ENVIRONMENT

The quasi–steady requirement for ISS is to provide microgravity acceleration levels less than 1 micro–g for frequencies below 0.01 Hz for the volume and durations specified in paragraph 4.2.1. The perpendicular component to the primary quasi–steady acceleration vector is not to vary more than 10% of the magnitude of the primary component. The first of the two periods over each coast period, shown in Figure 4.2.1.1–1, Quasi–Steady State Microgravity Contours Due to Gravity Gradient and Once–Per–Orbit Rotation Accelerations, will produce reduced quasi–steady acceleration due to the reduced drag experienced at higher Earth orbit than will normally be possible during the second period. The atmospheric drag component is time varying per orbit also, as shown in Figure 4.2.1.1–2, Drag Acceleration Profile Over One Orbit for Assembly Complete Configuration. The x direction component will vary primarily due to ISS cross sectional area change and due to atmospheric density change. The cross sectional area is largely influenced by the solar array profile and is greatest near the terminator when the sun appears over the forward horizon and when the sun disappears over the aft horizon. The orbital atmospheric density changes with the local time of day over the Earth's surface. This density change is due to the increased presence of gas molecules, largely following parabolic trajectories, beginning and ending in the heated denser atmosphere below. Solar heating increases the temperature of the upper atmosphere resulting in a larger peak occurring near the 2:00 PM local time position of the earth on each orbit.

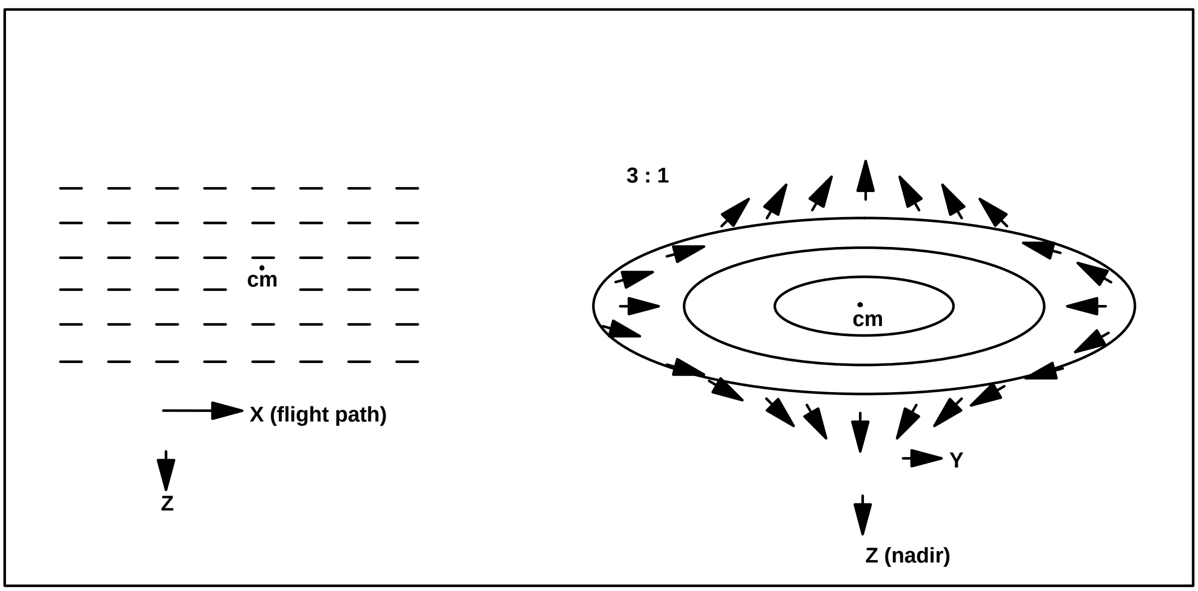


FIGURE 4.2.1.1–1 QUASI–STEADY STATE MICROGRAVITY CONTOURS DUE TO GRAVITY GRADIENT AND ONCE–PER–ORBIT ROTATION ACCELERATIONS

Smaller changes in y and z direction accelerations will accompany changes in x acceleration. The primary contributor to these off–axis accelerations is sine of Torque Equilibrium Angle (TEA) multiplied by the drag acceleration magnitude. The TEA angle may exceed 10 degrees due to the need to maintain an average aerodynamic torque on the ISS near zero. Otherwise, the angular momentum countering effects of the control moment gyros would eventually be exceeded. Atmospheric drag will also affect off–axis acceleration due to deflecting of molecules caused by the slanted solar arrays, which create an effect analogous to lift. The TEA change is minimized over each orbit by maintaining an average torque value near zero. The CMGs counter the short term torque changes to provide a near constant quasi–steady acceleration environment. Occasionally however, the torque equilibrium angle will require adjustment due to changing atmospheric or station mass properties conditions, resulting in short term angular accelerations and longer term shifts in the A * sin (TEA) change.

Large solar cycle changes are superimposed on these orbital variations, generally following the standard 11 year solar activity cycle, but also varying somewhat unpredictably due to short–term flare ups associated with increased sun spot activity. Increased solar activity results in generally increased drag; however, due to station keeping concerns, the ISS will be moved to a higher orbit commensurate with the solar cycle to reduce drag and extend the time reserve in–orbit. Consequently, the effects of solar cycle on payload drag are minimized.

The approximate 90 day cycle between planned reboost periods results in the largest atmospheric drag change. Following reboost, the ISS will be in its highest orbit, resulting in the minimum drag, lowest x acceleration period. The peak orbital drag during these periods should be on the order of 0.1 to 0.2 micro–g compared with the greater than 1 micro–g drag which will occur prior to reboost. The period of re–boost will present the largest accelerations, but this non–microgravity period will be relatively brief.

Gravity gradient produces another quasi–steady vibration contribution as shown in Figure 4.2.1.1–1 for the Local Vertical. This environment applies to the Local Vertical, Local Horizontal (LVLH) fixed attitude experienced at assembly complete and also during approximately half of the time prior to assembly complete. This contour profile will exist about the velocity vector line passing through the center of mass of ISS and extending indefinitely fore and aft. However, an X axis Perpendicular to Orbital Plane (XPOP) ISS attitude will frequently be experienced prior to assembly complete. This will occur whenever the solar angle exceeds approximately 35 degrees from the orbital plane, and will produce a greatly different and dynamic gravity gradient contribution. The structural X axis will experience the same out–of–orbit plane gradient previously experienced in structural Y. The structural Y and Z axis will experience changing gravity gradient components reaching a maximum gradient two thirds of that experienced in the Z direction. One micro–g quasi–steady environment will not be provided during the XPOP attitude to most payload locations and the perpendicular component at all payload locations will vary with time. Consequently, the requirement to minimize the perpendicular component requirement of quasi–steady acceleration will not be attempted during XPOP attitude.

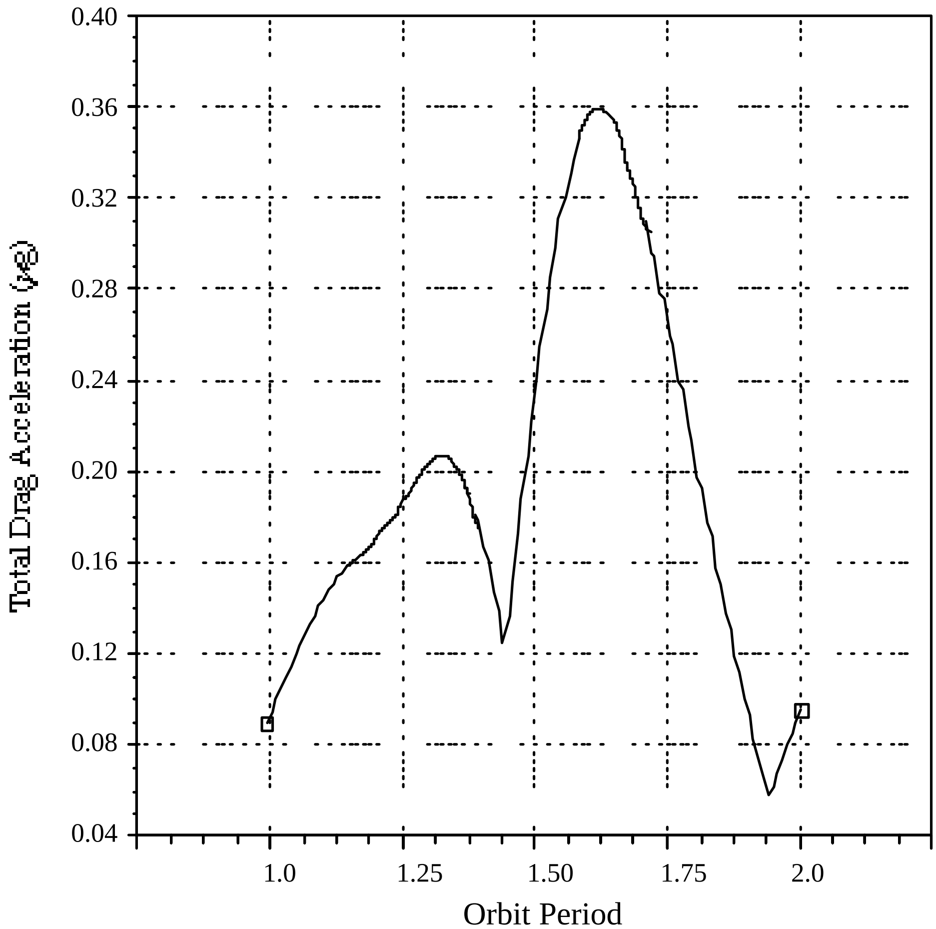


FIGURE 4.2.1.1–2 DRAG ACCELERATION PROFILE OVER ONE ORBIT FOR ASSEMBLY COMPLETE CONFIGURATION

4.2.1.2 VIBRATORY ACCELERATION ENVIRONMENT

ISS will provide a vibration microgravity environment during microgravity periods not exceeding the Root Mean Square (RMS) levels shown in Figure 4.2.1.2–1, Maximum Microgravity Vibration Environment during Microgravity Periods, for any one–third octave band when time averaged over any 100 second period.

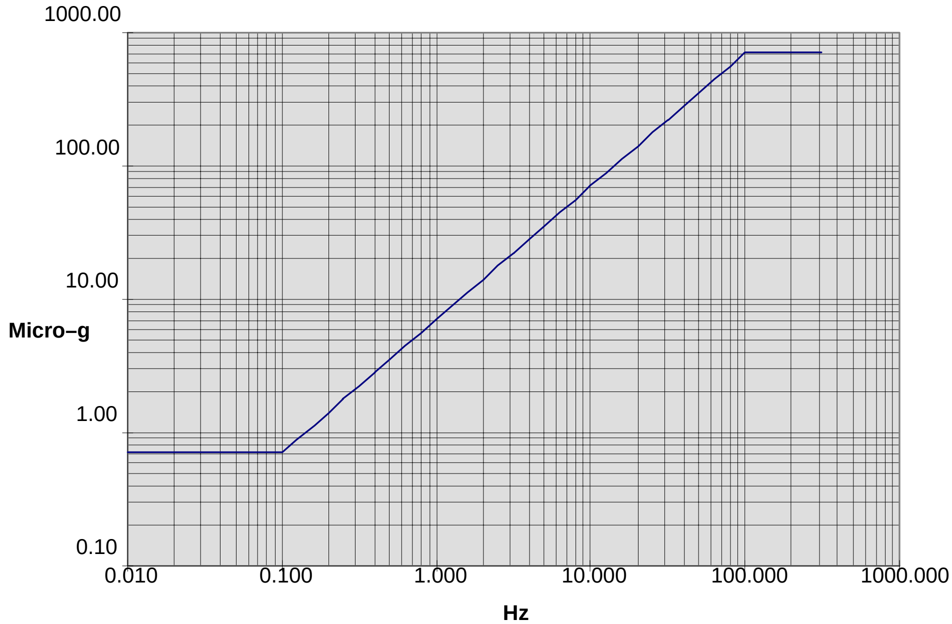


FIGURE 4.2.1.2–1 MAXIMUM MICROGRAVITY VIBRATION ENVIRONMENT DURING MICROGRAVITY PERIODS

4.2.1.3 TRANSIENT ACCELERATION ENVIRONMENT

During microgravity periods, transient disturbances are not to exceed an integrated 10 micro–g second amplitude–time product over any 10 second interval, nor exceed a peak amplitude of 500 micro–g for any duration.

4.2.1.4 NON ARIS VIBRATION AND TRANSIENT ENVIRONMENT

The Non–Isolated Rack Vibration Assessment (NIRA) is an estimate of the worst–case vibration environment that may be experienced by a non–ARIS rack. The version of this NIRA effective March, 2002 is shown in Figure 4.2.1.4–1. Although this was generated for the pressurized environment, the NIRA is the best estimate available for the typical worst–case microgravity environment of Attached Payloads.

The NIRA curve is revised periodically and reflects the summation of worst case disturbances which may occur during microgravity periods at worst case locations. Efforts are underway to reduce the amplitude of the peak disturbances such as crew exercise equipment, the source of the 3 Hz peak and rack–to–rack disturbances which are thought to dominate the frequency range between 7 and 15 Hz. As such, the NIRA curve should be a high estimate for the microgravity environment for any given payload at any given time. However, the data base from which NIRA is derived is not yet complete and actual measurements of flight hardware in flight configuration have only begun. The inputs of international partners are required, some of which are relatively early in their development. Also, the nature of vibration and transient response for ground measured structures may change when removed from normal earth gravity. Consequently, the ultimate vibration experienced by non–isolated racks is not likely to be known until the assembly of ISS is complete.

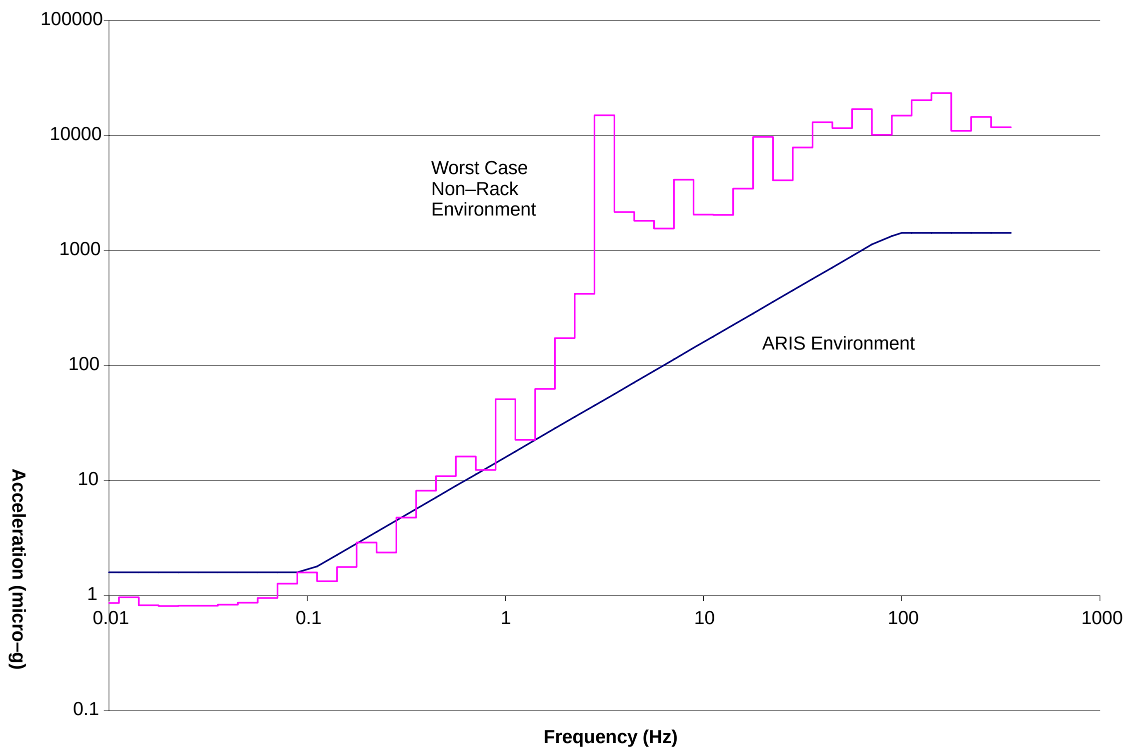


FIGURE 4.2.1.4–1 NON–ISOLATED RACK VIBRATION ASSESSMENT (MICRO–G VS HZ)

4.2.1.5 ISS MICROGRAVITY ENVIRONMENT MEASUREMENTS

ISS acceleration environment measurements are made for approved payloads by the Principal Investigator Microgravity Services (PIMS). Two accelerometer systems are typically used. The Space Acceleration Measurement System (SAMS) can be mounted within or external to racks to measure the environment between 0.01 Hz and 300 Hz. Although not available for Attached Payload site use, SAMS vibration at low frequencies (below 10 Hz) represents ISS modal effects and may be used as an indication of Attached Payload vibration environment in this limited frequency range. The Microgravity Acceleration Measurement System (MAMS) partially overlaps this region, but principally covers the lower frequency, quasi–steady range, below 0.01 Hz. Quasi–steady acceleration is measured only at one USL rack location, but with the assistance of ISS dynamics provided by the ISS Guidance and Navigation System, the quasi–steady microgravity conditions can be predicted at other locations in ISS, including the

Attached Payload sites. Selected real time data is supplied by PIMS over the Web and reports by increment are posted on the Web for PI use at http://pims.grc.nasa.gov/html/ISS_Reports.html

4.2.2 MICROGRAVITY REQUIREMENTS FOR PAYLOADS

Microgravity requirements placed upon payloads are a suballocation of the total environment allowed on ISS. This translates to an allocation to all payloads of approximately one–sixth of the total allocation, in a Root Sum Square (RSS) sense. This must be further suballocated based upon the number of active payloads at any given time. The same quasi–steady limit and transient limit are given to attached payloads and pressurized payloads. Vibration requirements differ because of differences in proximity and ISS dynamics.

4.2.2.1 QUASI–STEADY

Payloads must limit forces which influence the ISS quasi–steady environment to an average magnitude less than 0.02 micro–g within any 500 second period along any ISS coordinate system vector. This is a derived requirement estimate based upon extrapolation of the transient 10 micro–g second requirement to a time interval consistent with the 0.01 micro–g limit. Although 0.01 micro–g is a low value, it would require a substantial momentum producing payload to reach this value, which can normally be achieved only by continuous venting at levels which exceed the allowed rates for the vacuum/exhaust gas waste system. Movement of mechanisms within racks are unlikely to produce momentum changes approaching this limit.

Payloads must show that they produce no impulse in any direction greater than 10 lb–sec for any period of time less than 500 seconds. Technically, there is a distinction between quasi–steady and transients based upon duration, with 10 seconds being the dividing point. However, the 10 lb–sec applies to each, and the impulse with vibratory response also requires vibratory analysis as discussed earlier. Consequently, the 10 lb–s check may be performed by a single analysis or test.

4.2.2.2 VIBRATORY REQUIREMENTS

The vibratory requirements for pressurized payloads and attached payloads have the same objective, but differ as to degree and method of verification. Payloads must meet these vibratory requirements if they wish to operate during the microgravity periods where ISS resources are most available for payloads.

4.2.2.2.1 PRESSURIZED PAYLOADS VIBRATORY REQUIREMENTS

Slightly different requirements are imposed on ARIS and non–ARIS payloads due to interface differences, but the objective of requirements for each is primarily to protect other ARIS racks. No requirements are imposed to protect sub–rack payloads from other sub–rack payloads. Such requirements are the responsibility of the rack integrator.

Non–ARIS rack vibratory requirements may be met by either of three methods. One method requires the payload to be modeled or tested for interface force against a rigid interface. The other method requires that the payload model the rack in a PEI provided element model and verify that ARIS environment acceleration limits are met. The first method is simpler to apply, but may be more difficult to pass. A third method is available for very quiet payloads that permits application of source disturbance measurements to shortcut other modeling and test. If measured source disturbance forces are 100 times less than the rack interface force limits used for the first method above then no additional modeling or test is required.

4.2.2.2.2 ATTACHED PAYLOADS VIBRATORY REQUIREMENTS

Attached payloads may be verified by modeling or test against a massive rigid interface. SSP 57003 specifies transfer functions that are to be applied to the resulting interface forces for six degrees of freedom to predict accelerations at ARIS racks. The RSS is taken of the resulting ARIS location accelerations and compared with the limits specified in SSP 57003.

4.2.2.3 TRANSIENT REQUIREMENTS

As discussed in 4.2.2.2, the 10 lb–s transient impulse and quasi–steady limit may be treated by a single analysis. There is one additional transient requirement that limits the force that may be applied to ISS over any period of time to less than 1000 lbs. Vibration from transients, including the original impulse, are subject to the vibration limits discussed earlier.

4.2.3 GUIDELINES FOR PAYLOAD DEVELOPMENT

The microgravity requirements for ISS are unique and more stringent than those considered for other manned spacecraft in the past. This does not mean that equipment used in the past will not pass microgravity requirements. For instance, Space Shuttle was developed without microgravity requirements. Yet when the crew is less active, thrusters are disabled and the ku–band antenna system is disabled, the Orbiter environment meets the ISS requirement for on–board ARIS.

The area where ISS requirements are likely to be more stringent is in the lower frequency range below 15 Hz. This is due to the presence of low frequency modes on ISS that are not present on the relatively rigid Orbiter. Particular care is necessary for hardware that operates in the frequency range from 0.1 Hz to 10 Hz. Fortunately, forces generated in this range are frequently the result of noticeable mass motion and can generally be estimated by analysis..

If payload developers are not successful in providing microgravity verification, operation may be restricted to the non–microgravity periods of ISS operations. Based upon the 180 day per year minimum microgravity requirement, this would imply that the remaining portion of each year would be available for non–microgravity payloads. This may be so; however, the ISS is also under no obligation to provide significant power, heat rejection or crew time to payloads during non–microgravity periods, which may be reserved largely for upgrade, maintenance and human factors related activities.

4.2.3.1 QUASI–STEADY AND TRANSIENT REQUIREMENTS

The Attached Payload developer (i.e. EXPRESS Pallet Integrator, UCC Integrator) should show that for any period greater than 10 seconds that an average force greater than 0.02 pounds is not sustained along any axis. For example, it is sufficient to show that a translating 100 lbm can not move a distance greater than 3.9 inches from rest in 10 seconds while also showing that the linear acceleration assumption is valid.

Devices which have large angular momentum, such as large centrifuges, may introduce a precessional torque upon ISS which modifies the ISS torque equilibrium conditions, requiring slight changes in attitude. Such attitude changes may affect the quasi–steady acceleration at payload locations. Large angular momentum producing payload devices require separate analysis for this potential effect. Only hardware items that generate more than 100 ft–lb–s of angular momentum are required to report such disturbances.

4.2.3.2 ATTACHED PAYLOAD VERIFICATION

Attached payloads use a simpler three–point attachment arrangement as the primary load path, and either modeling or test may be used. PEI provided interface impedance calculations must then be used to adjust model or test results to determine interface force. Standard PEI provided transfer functions may then be used to determine worst–case payload accelerations, which may then be compared against the SSP 57003 specified limits. The interface impedance adjustment will generally show less interface force than would be determined by simple interface force measurement or modeling against a rigid massive interface, particularly for frequencies above 10 Hz.

The details for performing these procedures are provided in SSP 57916, Generic Payload Microgravity Control Plan (GPMCP).

4.2.3.2.1 SOURCE VIBRATION MEASUREMENT

Source vibration measurement is recommended for all significant disturbance devices. The acceleration test should be performed for each significant translational or rotational degree of freedom. Each axis should be measured in a free condition or in a lightly constrained condition from which the constraining effects may be removed by calculation. Assuming interface forces are derived from interface acceleration measurement, this is generally possible if the vibration isolation system used to isolate payload has a natural frequency less than one–third of the lowest significant disturbance force frequency.

Background measurements must be taken for both worst–case operating and non–operating background measurement cases. Background vibration may be removed for each one–third octave band by RSS contribution estimation using the relationship:

$$G_{actual}^2 = G_{measured}^2 - G_{background}^2$$

If the background level exceeds 100% of the maximum acceptable value in any frequency band, alternative means of measurement with reduced background vibration should be found.

A minimum of four independent samples for each case must be taken from which the one–sigma estimates of measured and background acceleration must be applied. The force and moment magnitudes may then be calculated from the accelerometer location geometry and measurements of the mass properties of the test fixture.

4.3 ELECTRICAL POWER SYSTEM

Attached Payloads delivered to the ISS by the Shuttle should nominally expect to be unpowered during transfer to the ISS for up to 4.5 hours. Payloads that are unable to withstand a lack of power for this duration must prearrange with the ISS for special accommodations, or provide their own power source.

This section describes the suitability of the ISS Electrical Power System (EPS) to accommodate payloads requiring electrical power at flights UF–3 and UF–4 and at the completion of ISS assembly. During the assembly of ISS, electrical power generation hardware and software will be installed to provide power to operate the ISS hardware as well as user payloads. Prior to Assembly Complete, payloads should be capable of withstanding several periods of approximately eight hours of power disruptions. Planned power outages will be documented in SSP 50112, Operations Summary Document. However, unplanned payload power outages may also occur.

The electrical power used to support the operation of ISS, including payloads, is generated by the incidence of solar energy onto Photovoltaic (PV) arrays. PV arrays convert solar energy into electrical energy. Once converted, the energy produces a direct current that is guided to payload locations internal and external to the ISS pressurized elements. The ISS has eight PV arrays. Each PV array is physically and functionally isolated from the other arrays. Therefore, ISS contains eight separate electrical power sources for generating electricity. The arrays are symmetrically attached to the ISS truss segments. The truss segments supporting the PV arrays are located on both the port and starboard sides of the ISS. Each side contains four arrays connected to segments P4 and P6, and S4 and S6, as shown in Figure 4.3–1, Electrical Power System. Each array attached truss segment has two arrays symmetrically located to the individual segment. Two arrays in this single truss segment configuration are known as a PV module (e.g., PV modules P4, S4, P6 and S6).

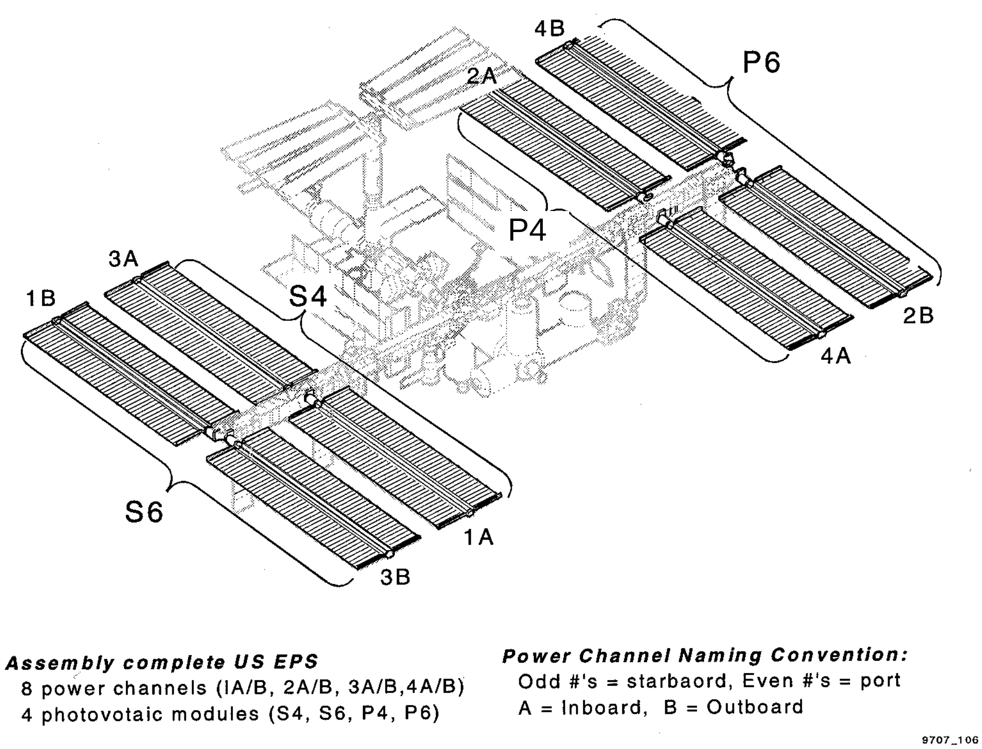


FIGURE 4.3–1 ELECTRICAL POWER SYSTEM

4.3.1 PRIMARY POWER SYSTEM

The energy produced by a PV array is routed on two paths. One part is used to deliver energy to batteries for energy storage, the other part connects to ISS electrical power consuming equipment via a network known as the Main Bus Switching Unit (MBSU). ISS is equipped with four MBSUs each containing two channels. A total of eight isolated channels receive power feeds from the eight arrays. Power from each array can be channeled to multiple Electrical Power Consuming Equipment (EPCE) due to the MBSU design, see Figure 4.3.1–1, MBSU Power Distribution. The designation ”RBI” stands for ”Remote Bus Isolator”. The design of the MBSU provides capability to electrically connect to each other by implementing the use of cross–ties. This feature provides redundancy in supplying power to ISS EPCE and payloads. The sharing of power between critical subsystems is such that the MBSU switching configuration will not be altered except in emergency situations.

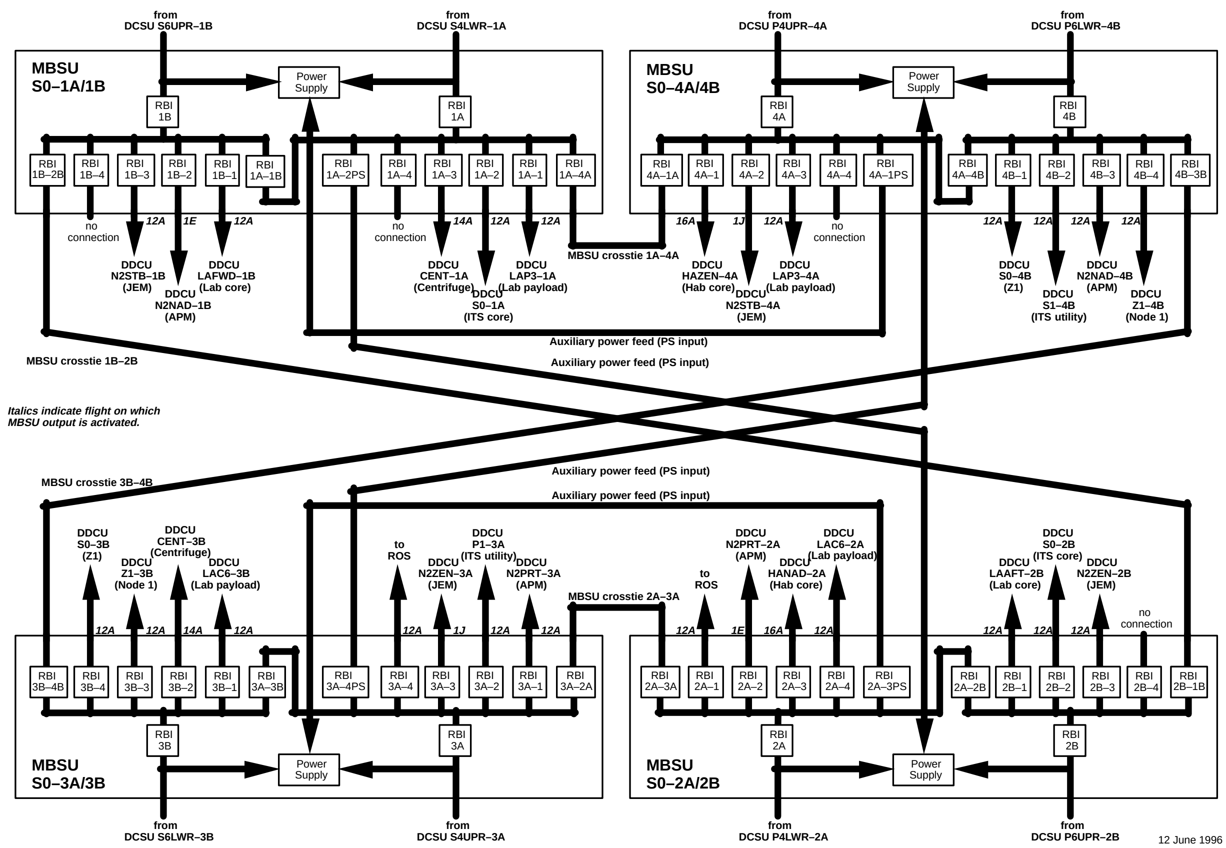


FIGURE 4.3.1–1 MAIN BUS SWITCHING UNIT POWER DISTRIBUTION

Each channel of each MBSU receives one primary input feed from an individual PV array. The output(s) consists of up to four feeds. Each MBSU output feed supplies power to a Direct Current–to–Direct Current Converter Unit (DDCU). The DDCU is responsible for converting primary direct current (dc) power into secondary dc power using a transformer. Each DDCU has one primary power input and one secondary power output. The primary power input voltage to the DDCU is typically 160 Volts Direct Current (Vdc) but can vary over a wide range, while the DDCU output is specified to be 124 Vdc, which is the prescribed voltage for all users of the Secondary Power System. If any other voltage level is required by user loads, (e.g., payloads or crew equipment) then it is the responsibility of the user to perform the conversion from 124 Vdc to the required voltage. The DDCU’s main purposes are to:

- provide dc power conversion from primary to secondary power
- provide isolation between two or more power sources
- provide isolation between loads connected to other DDCUs
- regulate primary power within specified voltage and current limits
- provide capability to shift power between power sources.

4.3.2 SECONDARY POWER SYSTEM

The first step in the local power distribution is the conversion from primary power (~160 Vdc). Power conversion occurs in various areas throughout the ISS, such as truss segments and other locations where users require secondary power. After conversion, secondary power is distributed through a network of power distribution assemblies. The active components within these assemblies are remotely commanded switches that control and monitor power through the network to individual users, such as systems, payloads, crew equipment, EPS components, etc.

Electrical power for S3/P3 Attached Payloads is provided via UMA electrical connectors at the payload attach site. Figure 4.3.2–1 gives electrical interface details of UMA connectors. The UMA interface supports the transfer of electrical power to the Attached Payload at a maximum of 25 amps (A) between 113 and 126 Vdc. The UMA interface is capable of providing power across either of two circuits depending upon operational constraints. Availability of power will depend upon stage specific ISS operational constraints. The Attached Payload Port and Starboard Interface (APPI) is designated an Interface C power interface as defined in SSP 30482, Electrical Power Specifications and Standards, Volume 1.

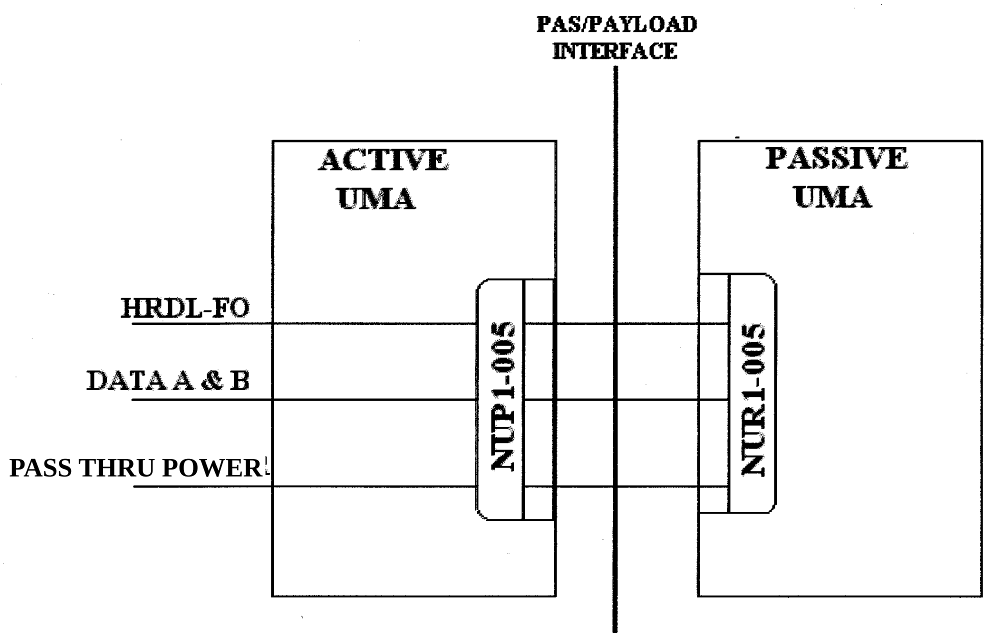


FIGURE 4.3.2–1 ELECTRICAL POWER SYSTEM INTERFACE

4.3.2.1 ATTACHED PAYLOAD CONNECTORS AND PIN ASSIGNMENTS

S3 PAS and P3 UCCAS avionics interfaces terminate in the active UMA connector, NUP1–005, as defined in SSP 57004, Table 3.2.1–1. Attached Payloads utilize the passive UMA connector, NUR1–005, as defined in SSQ 21637 to mate with the active UMA and correspond to the pin assignments in SSP 57004, Table 3.2.1–1. The Boeing part number for the passive UMA is 1F70162–1.

4.3.2.2 ELECTRICAL BONDING

At the conclusion of the CLA latching operation (Attached Payload berthed), the Attached Payload and the S3 PAS/P3 UCCAS will effectively form a single structural unit. Electrical bonding of the Attached Payload connected to Interface C then occurs at the conclusion of UMA mating and is in accordance with SSP 30245, Space Station Electrical Bonding Requirements. Figure 4.1.2.1.2–1 depicts the guide vane well bottoms that are flattened to accommodate electrical resistance Class ”R” bonding at the guide pin interface in the final berthed position for the fully mated, preloaded and deflected system.

4.3.2.3 PAYLOAD MAIN POWER AND HANDLING CAPABILITY

Attached Payload main power is provided through the main power feeds to a maximum capability of 3kW for nominal payload operations. The specific power handling characteristics of the Attached Payload locations for this document are shown in Table 4.3.2.3–1.

TABLE 4.3.2.3–1 ELECTRICAL POWER SYSTEM CHARACTERISTICS AT ATTACHED PAYLOAD LOCATIONS

LOCATION	MAIN (kW)	MAIN RPC CURRENT RATING (Amps)	AUXILIARY RPC CURRENT RATING (Amps)	RPC TYPE main/aux.
ITS S3 PAS–1	3	25	25	II/II
PAS–2	3	25	25	II/II
PAS–3	3	25	25	II/II
PAS–4	3	25	25	II/II
ITS P3 UCCAS–1	3	25	25	II/II
ITS P3 UCCAS–2	3	25	25	II/II
MCAS	1.356	12	12	I/I

4.3.2.4 IMPEDANCE LIMITS AT ATTACHED PAYLOAD POWER INTERFACE

Electrical impedance must be limited to acceptable values to ensure a balanced and stable electrical power network. The source impedance must also be recognized by the payload to ensure proper performance of the payload. The source impedance limits are defined in SSP 57004. The load impedance limits are defined in SSP 57003.

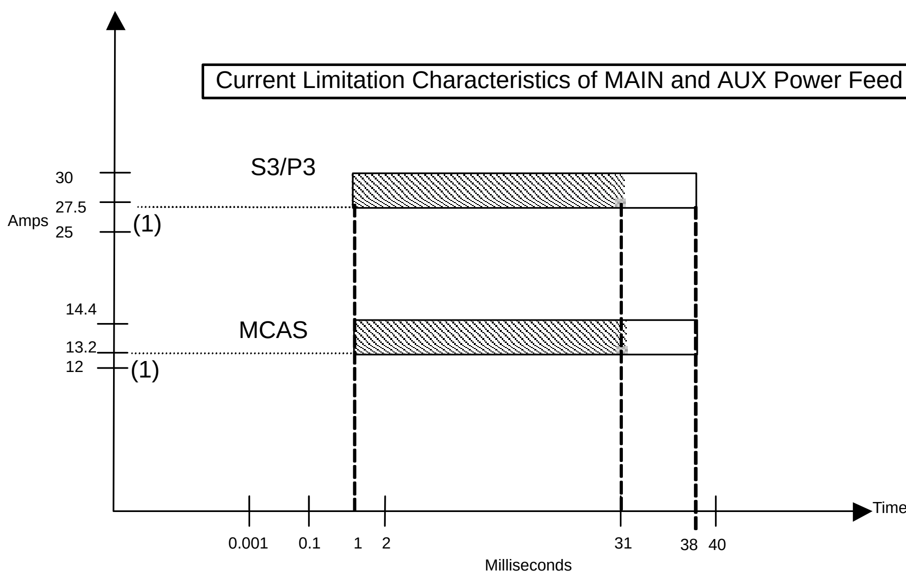
4.3.2.5 REMOTE POWER CONTROLLER MODULE (RPCM) OVERLOAD LIMIT

The ISS power source will provide protection to the APPI for overload conditions by means of a Remote Power Controller (RPC). The overload limitation characteristics of the power feeders are defined in Table 4.3.2.5–1 and Figure 4.3.2.5–1. The shaded regions in the figures show the current limit regions from the time the protection devices start to control the current within the specified range to the maximum time where the protection device trips and interrupts the current flow. Nominal current ratings are 25 amperes. The current at the S3/P3 APPI will be controlled to within the limiting level of 27.5 to 30 amperes within 1 millisecond. The current at the MCAS power interface will be controlled to within the limiting level of 13.2 to 14.4 amperes within 1 millisecond. The RPC will trip if the current remains in the limiting region up to the decision time of 34.5 ± 3.5 milliseconds.

TABLE 4.3.2.5–1 DETAILED UPSTREAM PROTECTION CHARACTERISTICS

POWER INTERFACE	MAIN PWR FEEDER			AUX PWR FEEDER	
	LOWEST CURRENT LIMITATION LEVEL	MINIMUM TRIP THRESHOLD	MINIMUM* TRIP DECISION TIME	LOWEST CURRENT LIMITATION LEVEL	MINIMUM* TRIP DECISION TIME
ITS S3 PAS	27.5 A	27.5 A	31ms	27.5A	31ms
ITS P3 UCCAS	27.5 A	27.5 A	31ms	27.5A	31ms
MCAS	13.2 A	13.2 A	31 ms	13.2 A	31 ms

*Trip decision time at or above limiting/trip threshold (27.5 A to 30.0 A at S3 and P3 APPI and 13.2 A to 14.4 A at MCAS power interface).



Note (1) During the first 1 millisecond the limiting level may be higher or lower than specified.

FIGURE 4.3.2.5–1 ITS S3/P3/MCAS OVERLOAD PROTECTION CHARACTERISTICS

4.4 COMMAND AND DATA HANDLING

The ISS C&DH system consists of hardware and software that provide services for command, control, and data distribution for all ISS systems, subsystems, and payloads. The top level (system level) C&DH architecture contains redundant Command and Control (C&C) Multiplexer Demultiplexers (MDM), and MIL–STD–1553B control buses. The payload service includes the Payload MDM for Low Rate Data Link (LRDL) (1553B local bus) data and command distribution, and a High Rate Data Link (HRDL) for payload–to–payload communication and data downlink service. LRDL (other than payload safety–related) data is downlinked via the Ku–band to the ground. Safety–related data is routed via the C&C MDM to the S–band data services for downlink. The Portable Computer System (PCS) is used by the onboard crew for the command and display interface. Payload commands can be uplinked from a ground site, issued from the PCS, or issued by a Payload MDM automated procedure. The C&DH architecture diagram is shown in Figures 4.4–1 and 4.4–2. Note that the Attached Payload accommodations do not include a Medium Rate Data Link (MRDL) interface.

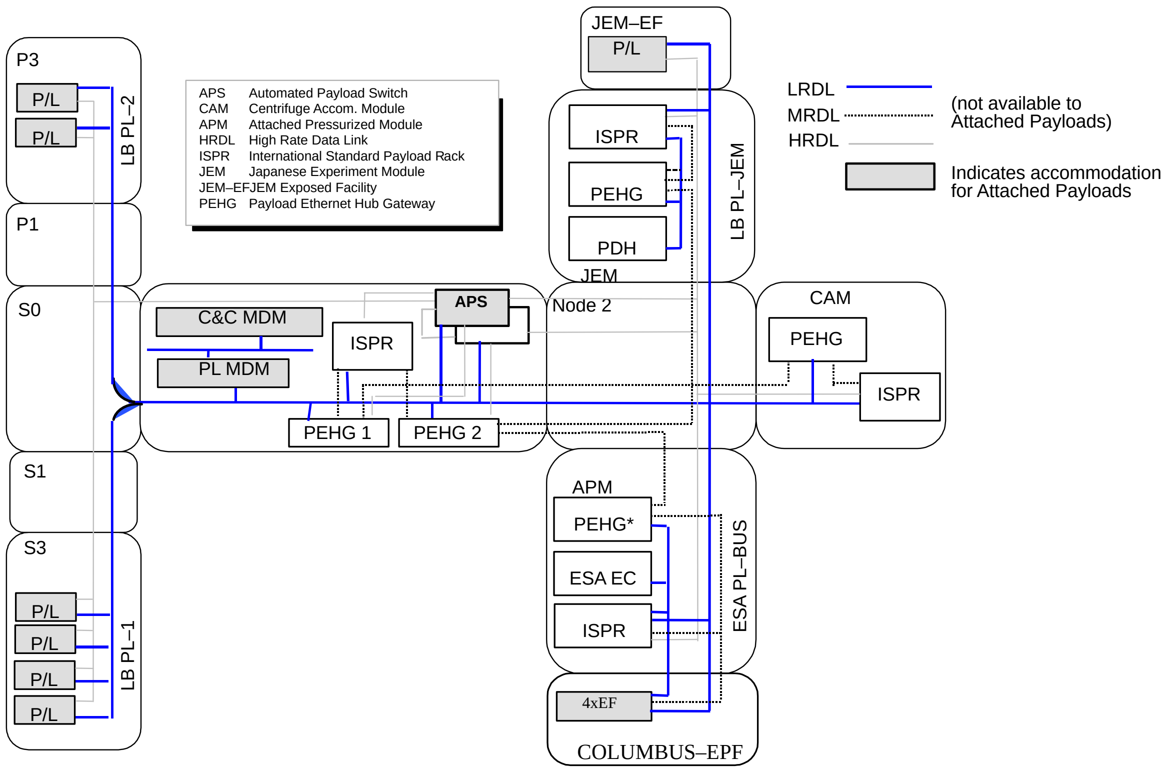
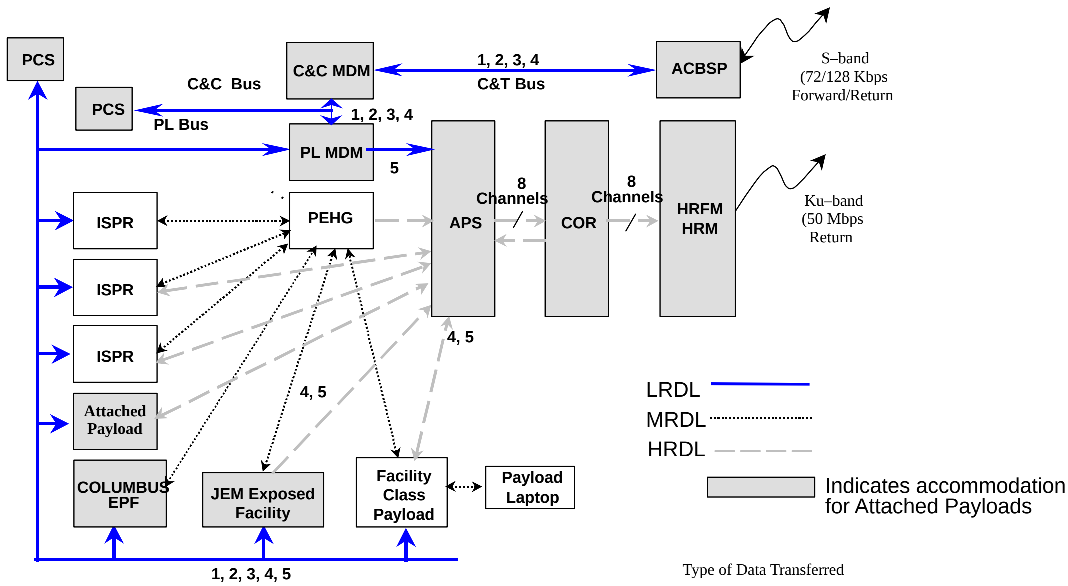


FIGURE 4.4–1 C&DH ARCHITECTURE



Note:

- All LRDL and MRDL lines are bi–directional
- USOS data lines shown only

Type of Data Transferred

1 commands to payloads
2 health and status, C & W
3 broadcast ancillary data
4 payload files
5 telemetry data

FIGURE 4.4–2 C&DH PAYLOAD ARCHITECTURE FUNCTIONAL DATA FLOW

4.4.1 PAYLOAD COMMANDS AND DATA TYPES

Payload commands and the following data types are transferred: Payload Health and Status Data, Payload Caution and Warning (C&W) Data (Safety), Ancillary Data, Payload Telemetry Data, and Payload Files. Payload Files are both to/from a Payload to a Payload or System. Data types are listed with the associated maximum rates shown in Table 4.4.1–1.

TABLE 4.4.1–1 C&DH DATA TRANSFER

Type of Data Transferred	Payload to/from		by Data Link	
	Individual P/L Data Rate	Aggregate P/L Data Rate [5]	LRDL	HRDL
commands (to payloads)	10 commands per second [3]	8 commands per second [4]	X	
health and status C&W	18720 bps 160 bps	192 kbps (s–band) 256 kbps (Ku–band)	X	
payload ancillary data broadcast ancillary data	3840 bps 8960 bps	N/A	X	
payload files	≤ 40.96 kbps	≤ 40.96 kbps	X	
low rate telemetry data[1]	≤ 10240 bps		X	
		100 kbps		X
high rate telemetry data[2]	≤ 100 Mbps	≤ 20 Mbps		X

NOTE: Based on five (5) Payloads per LRDL

1 low rate data is sent via the HRDL to the ground

2 high rate data aggregate is total available after video

3 P/L MDM can support 10 commands per second (allows buffering of commands)

4 C&C MDM can support 8 commands per second (ground command through–put limit)

5 Aggregate payload refers to payloads on USOS C&DH System (internal and external P/Ls)

4.4.1.1 PAYLOAD EXECUTIVE PROCESSOR (PEP)

The PEP resides in the Payload MDM and provides monitoring, control, and coordination of the payload activities on the ISS. The PEP is driven by configuration tables which provide operational data to PEP services and utilities to support payload operations. These configuration tables will change as the ISS payload complement changes. The Payloads Office manages the configuration tables and the Payload Operations Integration Center (POIC) implements any changes.

The following describes the payload services of the PEP that provide the user with a mechanism for obtaining or sending data/commands to the payloads. Payload services are available to the users as scheduled during the weekly planning process. Access to the PEP is through the C&C MDM control bus on the system side of the Payload MDM and the payload local buses on the payload side. The payload local buses connect to the PCS, Automated Payload Switch (APS), Payload Ethernet Hub/Gateway (PEHG), and payloads. The PEP services are specified in SSP 52050.

A. Procedure Execution Service.

This capability, in conjunction with Timeliner, provides an on-orbit configurable capability to control payload operations based on command input or payload status feedback. This service is activated when a Timeliner Command is generated from the crew (via PCS) or ground upon request from the payload developer. Upon receipt of the command/request, the Procedure Execution Service issues a command to the Timeliner Executor identifying the User Interface Language (UIL) bundle (sequence of Timeliner User Interface Language statements), sequence, and action specified by the command. Once the bundle has been installed via an Install Bundle command, a payload can control the execution of the procedure by placing the Procedure Execution Request structure (given in Table 3.2.3.7–1 of SSP 52050) in the Payload Request location in the payload's health and status. A Procedure Execution Request is invalid if there is no sequence associated with the Sequence Identifier provided in the request. A Procedure Execution Request is unauthorized if the request (Start/Stop/Resume) does not correspond with authorization data located in PEP increment-specific configuration tables.

B. Health and Status/Safety Service.

Payload health and status/safety data is the set of flight information required by the POIC to support real-time operations and analysis. It includes status parameters from the payloads and any onboard systems and subsystems for which the POIC is responsible. The payload health and status data is required by the POIC to monitor and manage payload operations, and is available to the payload user upon request.

Payload safety data is the set of safety-related flight data defined by the PD/PI, in conjunction with the Payload Safety Review Panel (PSRP), and is required to support real-time operations and analysis to ensure the safety of the payload. It is contained in the health and status data but is processed and monitored independent from payload health and status data.

The PEP processes on-orbit payload operations health and status data and safety data. The PEP assembles a data stream of payload-specific health and status data to the POIC via the Ku–band. The payload health and status data and safety data are received by the PEP via the payload local 1553B bus (LRDL). The Consultative Committee for Space Data Systems (CCSDS) downlink packet is created by the PEP from data (with a CCSDS header) provided by the payload. The downlink packets are sent to the High Rate Frame Multiplexer (HRFM) via the HRDL for Ku–band downlink. The payload safety data is sent to the C&C MDM for inclusion in the S-band Ku–band downlink. The PEP also utilizes payload health and status for limit monitoring, sending parameters to the PCS for crew display, to support automated procedure execution and to route ancillary data.

Figure 4.4.1.1–1 illustrates the health and status bit allocation format. The Subset Identifier defines a unique payload's data. The PEP will use the subset identifier to identify the length of the data and the storage area for the data. To request a PEP service (i.e., start and stop ancillary data service and low rate telemetry service, file requests, and procedure requests), the payload must place the appropriate request structure in the payload request location in the payload's health and status data. The format of the payload request data is given in Table 3.2.3.7–1, Service Requests, of SSP 52050.

For the PEP to begin collecting payload health and status data and safety data, a Payload Startup Notification Command must be received by the PEP. Prior to the PEP receiving the command, the payload power and processor must be activated. For the PEP to cease collecting payload health and status data and safety data, a Payload Shutdown Notification Command must be received by the PEP. These commands can be generated from the crew, ground, or Timeliner. The PEP collects a payload's health and status data and safety data at either one data reading in 10 seconds or one per second on a per RT basis as defined in the PEP increment–specific configuration tables. The PD defines data limits in the C&DH data set. The Payload MDM will use the length in word 3 of the CCSDS header to determine the actual number of messages to be collected for the health and status packet. Each message contains 32, 16–bit words. This message is known as a "boxcar". For additional information regarding the PEP Health and Status Service, see Section 3.2.3.5, Health and Status Data, of SSP 52050.

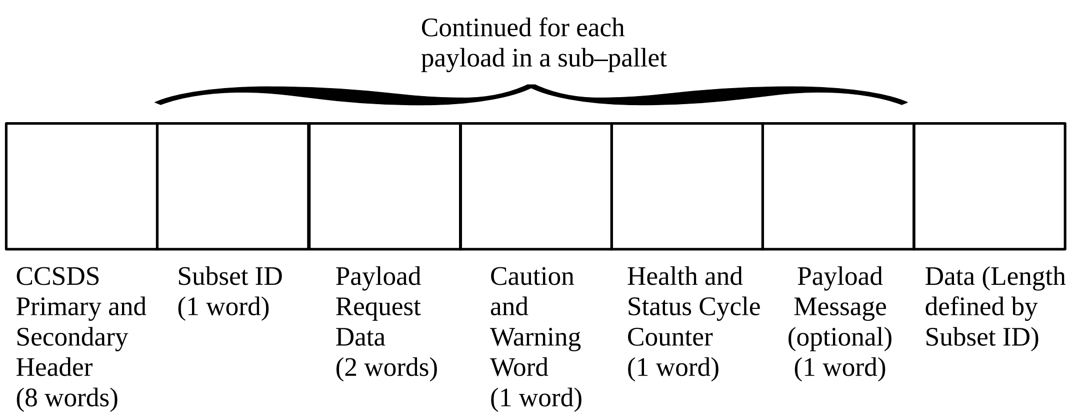


FIGURE 4.4.1.1–1 PAYLOAD HEALTH AND STATUS BIT ALLOCATION FORMAT

C. Mass Storage Device (MSD) Service.

The MSD service has several functions. It provides a means by which payload applications can access data on the payload MSD. This function limits access by payload applications based on authorization data generated by the POIC. This authorization data specifies access privileges of payload applications for individual payload MSD files. To manage the files, the payload must place the File Request Structure (given in Table 3.2.3.7–1 of SSP 52050) in the Payload Request location in the payload's health and status data. For further information regarding payload file transfer to/from the PEP, see Section 3.2.3.9, File Transfer, of SSP 52050.

The MSD Service provides the POIC a means to manage files on the payload MSD. The PEP may downlink data from identified payload MSD files via Ku-band telemetry upon command. The PEP also responds to commands to delete files from the payload MSD.

The MSD Service provides a non-volatile MSD for storage and retrieval of Timeliner bundles, files for laptops, files for payloads, log files, the PEP configuration tables, etc. in the MDM. The MSD provides a storage capacity of 1000 Mbytes in the form of a Solid State Mass Memory Unit (SSMMU). MSD management transfers files to and from the Payload MDM or direct to the Ku-band for downlink. The downlink data transfer rate is 1.2 Mbps, for all payloads collectively.

D. Ancillary Data Service.

Ancillary data is a selected subset of core system data and other onboard generated data, including payload generated data, required to support experiment/payload analysis by users, for use by onboard payloads during operation and for operation of onboard payloads by the crew and ground controllers. Ancillary data describes the flight environment in which the payload is operated and includes information such as time of event, temperatures, state vectors, Station configuration, and microgravity constants. Table 4.4.1.1–1 provides a representative list of ancillary data types. The list is not exhaustive.

TABLE 4.4.1.1–1 ANCILLARY DATA TYPES (EXAMPLES)

SYSTEM	PARAMETERS
Communication and Tracking	Bandwidth Utilization Status Orbital Replacement Unit (ORU) Status and Performance/Failures High Rate Link Utilization Status
Electrical	Current Usage Supply Voltage RPCM On/Off Power Status
Rates	Body Rate X–Axis, Y–Axis, Z–Axis
LVLH Attitude M–50	Quaternion (1–4)
State Vector	X, Y, Z–Comp of Current Position Vector X, Y, Z–Comp of Current Velocity Vector
Miscellaneous	Greenwich Mean Time (GMT) Mission Elapsed Time Station Modes Acceleration Levels Vibrations Crew Operations/Activity Sun Vector

The PEP provides ancillary data to the payload based on ancillary data sets predefined by the user in the C&DH data set and POIC. A payload may request the PEP to provide ancillary data as a one-shot transmission or on a cyclic basis of one data reading in 10 seconds or one per second per payload basis based upon the selection of the predefined ancillary data set(s). The PEP accepts commands from the crew, ground, or Timeliner to initiate and terminate the cyclic downlink of ancillary data, in CCSDS packet format.

This service will be activated for a particular payload via the Start Ancillary Data Service Request. The service is terminated via a Stop Ancillary Data Service Request. To receive or terminate ancillary data, the payload must place the appropriate ancillary data service request structure in the Payload Request location in the payload's health and status data.

Table 3.2.3.8–1, Ancillary Data Packet Format, of SSP 52050 illustrates the message format for Ancillary Data which is sent by the PEP to a payload. A payload can request one data set at a rate of 10 times per second per Payload Request, but the PEP will send only one data set to a payload for any given request. A data set is limited to 32 words (including the CCSDS header, ancillary data set ID, and up to 23 data words). There is a maximum of 100 data sets allowable for any payload complement, without reconfiguring the Payload MDM.

E. Operations Control Service.

The crew, ground, or Timeliner may command the PEP for all PEP system mode changes. The PEP receives operations commands, provides responses to these commands, and executes the required activity. The commands are used for Emergency Payload Shutdown, Operation Shutdown, and Suspended Payload Operations, and to control the PEP modes.

The modes are (1) idle and (2) normal payload operations. Idle mode is used to initialize internal PEP data and automatically transitions to normal payload operations mode.

The following defines what services or capabilities are available to the payload during each PEP mode:

(1) Idle: No POIC telemetry or payload services are provided.

(2) Normal Payload Operations: Nominal operating mode for conducting payload activities. Within this mode individual payloads are started, operated, shut down, etc. All PEP support and management functions are available.

F. Low Rate Telemetry Service.

The PEP supports the low rate downlink of payload data. The PEP accepts low rate telemetry data from payloads and sends the data to the ground via the HRDL for downlink through the Ku–band system.

This service may be activated for a particular payload via the Start Low Rate Telemetry Request. The service is terminated via a Stop Low Rate Telemetry Request. To receive or terminate low rate data, the payload must place the appropriate low rate telemetry request structure in the Payload Request location in the payload's health and status. The PEP accepts commands from the crew, ground, Timeliner, or payloads to initiate and terminate low rate service. The PEP collects a payload's low rate science data at either a one data reading in 10 seconds or one per second on a per payload basis (the Payload MDM process rate is 1.0 Hz).

A Start Low Rate Telemetry Request is invalid if the requesting payload is currently being provided the Low Rate Telemetry Service. A Stop Low Rate Telemetry Request is invalid if the requesting payload is currently not being provided with Low Rate Telemetry Service.

Upon receipt of a valid Start Low Rate Telemetry Request from a payload, the Low Rate Telemetry Service starts to downlink data for a specified payload. The POIC health and status data will indicate which payload(s) is(are) currently being serviced. Payload low-rate telemetry data (its own CCSDS formatted packet) will be polled by the PEP from payload transmit subaddress # 8. The data is then downlinked via HRDL to the Ku–band. The data is routed on the HRDL to the Ku–band entry point (High Rate Frame Multiplexer) through the APS. The transfer of low rate telemetry payload downlink data from payloads to the PEP will support up to 100 kbps of payload data on an individual local bus. For additional information regarding the mechanics of the PEP Low Rate Telemetry Service, see Section 3.2.3.10, Low Rate Telemetry, of SSP 52050.

Upon receipt of a valid Stop Low Rate Telemetry Request, the Low Rate Telemetry Service assures that the downlink data is currently active for that payload and then discontinues providing the downlink data for the payload.

G. Limit Monitoring Service.

The Limit Monitoring Service monitors payload and payload support system data to detect out-of-limit conditions. A Limit Monitoring response consists of initiating predefined exception processing and notifying the crew and POIC of out-of-limit conditions. Limit Monitoring processing is predefined and may result in the issuance of any legal command, including a command to execute an automated sequence, notify the Portable Computer System (PCS) or payload laptops, and/or notify the C&C MDM of a Limit Monitoring event.

The PEP must receive the Payload Startup Notification Command indicating the payload is active before Limit Monitoring Service is initiated.

Up to 250 data items per Payload MDM (i.e., payload data items, core system data items, APS data items, etc.) are allowed for limit checking, with two exception levels for each data item. If an out–of–limit condition is detected, a corresponding command or sequence will be executed, and/or the condition will be annunciated to the C&C MDM.

H. Payload Commanding Service.

A payload command can be sent by the crew, ground, or Timeliner and is routed through the PEP for an initial verification before the command is passed to the payload. The command will contain, within the primary CCSDS header, the appropriate Application Process ID (APID) corresponding to the RT being commanded. The PEP makes no interpretation of the command other than to distinguish it as a non-PEP command so that verifications can be conducted before the command is forwarded.

One command can be no more that 64 16-bit words (command through the OIU is limited to 62 words) including the CCSDS header. Payload commands destined for payloads located on the local bus are transferred to the RT Commanding Subaddress at a maximum rate of 10 commands per second. The Payload MDM can process up to 10 commands per second from the C&C MDM (maximum number of uplink command is 8 commands per second), or one command per second from each PCS (total of five PCSs on the payload MDM local bus).

I. Broadcast

(1) Time: Payload MDM will broadcast the station time to payloads for reference at a 1.0 Hz rate which is accurate to 2.5 ms, referenced to the Global Positioning System (GPS) system.

(2) Broadcast ancillary data: The Payload MDM will broadcast 64 words of Broadcast Ancillary data (core data) per 100 ms up to 100 sets. Each set includes a CCSDS header, 1.0-Hz data segment (once per second) and 0.1-Hz data segment (once every 10 seconds).

(3) Broadcast sync: The Payload MDM broadcasts a Broadcast sync with data message on all lower level 1553B buses every 100 ms.

J. File Transfer

Transfers of bulk file data between a payload RT and the PEP are initiated through the PEP Service Request mechanism. The mechanism for causing the PEP Service Request to be issued by the payload RT is determined by the payload developer.

The transfer of file data in either direction (PEP to RT or RT to PEP) requires a degree of handshaking between the source and destination to ensure completeness and accuracy. To achieve a complete and accurate data transfer, the file data will be passed in 256 word blocks that are enclosed in nine separate 32–word messages (288 words). Also included in the 288 words is CCSDS header information and checksum, the total file length in bytes, the number of words (of the 256 words) in the data field, and a Block Number.

For additional information on File Transfers, see SSP 52050, Section 3.2.3.9.

4.4.1.2 CAUTION AND WARNING

The ISS alerts the crew to abnormal/hazardous conditions via the Caution and Warning (C&W) system. Payload health and status and safety related parameters are monitored to alert the crew of payload abnormal/hazardous conditions on ISS via the Payload MDM.

The C&W system classifies events into 4 classifications.

A. EMERGENCY (CLASS I)

All of the defined ISS emergency conditions are reported by the ISS systems. Attached Payloads and equipment will not be allowed to report an emergency condition.

B. WARNING (CLASS II)

A warning requires someone to take action immediately. Warnings are used for events that require manual intervention and for notification when automatic safing fails.

A warning situation is defined as a:

(1) A precursor event that could manifest to an emergency condition (open ready to latch indicator, over–pressurization of a pressure vessel, inadvertent release of a contaminant) and

(a) automatic safing has failed to safe the event or

(b) the system is not automatically safed (i.e. requires manual intervention).

(2) An event that results in the loss of a hazard control and

(a) automatic safing has failed to safe the event or

(b) the system is not automatically safed (i.e. requires manual intervention).

C. CAUTION (CLASS III)

A caution requires no immediate action by the crew. Automatic safing has controlled the event.

A caution situation is defined as:

(1) A precursor event that could manifest to an emergency condition (open ready to latch indicator, over–pressurization of a pressure vessel, inadvertent release of a contaminant) and automatic safing has safed the event (i.e. the system does not require manual intervention).

(2) An event that results in the loss of a hazard control and automatic safing has safed the event (i.,e. the system does not require manual intervention).

D. ADVISORY

An advisory event can be set by the payload developer for the following purposes:

(1) Advisories are set primarily for ground monitoring purposes (advantageous due to limited communication coverage and data recording).

(2) Data item that most likely will not exist permanently in Telemetry List but should be time tagged and logged for failure isolations, trending, sustaining engineering, etc.

The C&W system software is in the Command and Control (C&C) MDM. To access the C&W system, payload data must identify a C&W word in the health and status data communicated to the Payload MDM. That word must be coded by the payload to identify the condition of the payload as no–problem or one of the event classes defined above. The Payload MDM compares that value with stored data values in the Limit Check Table (LCT) to determine the event classification communicated from the payload. The Payload MDM will then communicate the event and classification to the C&C MDM for annunciation on the C&W system.

4.4.2 PAYLOAD MULTIPLEXER/DEMULTIPLEXERS

The Payload MDM provides the US payload complement with command, control, and monitoring functions. The software that implements the Payload Executive Processor (PEP) is resident in the Payload MDM. The Payload MDM provides one single redundant 1553B payload local bus for command/data distribution to (and gather data from) the devices and payloads attached to that 1553B payload local bus. A total of four separate single redundant payload local buses interface with payloads in the external sites.

The 1553B payload local buses provide an interface to the external payload locations (i.e., Attached Payloads). The 1553B payload local buses provide the payloads with commands from onboard automated payload procedures, PCSs, and ground control centers, and data such as timing, broadcast ancillary data (core system data), file transfer, and ancillary data (payload and system data). Payloads send their payload health and status/safety data, file transfer data, and low rate payload telemetry data through the 1553B payload local bus to the Payload MDM.

4.4.3 AUTOMATED PAYLOAD SWITCH

The payload HRDL data is routed via the Automated Payload Switch (APS). The APS provides an optical to electrical crossbar switch mechanism, and electrical to optical converter for routing HRDL signals from HRDL input ports to HRDL output ports. The APS provides HRDL waveform regeneration for all HRDL inputs. The switching configuration is controlled via instructions from the payload MDM received over the 1553B bus.

The ISS provides two APSs. Each APS has 44 HRDL input ports and 36 HRDL outputs. Within these 36 output ports, four of them are routed to the HRFM for downlinking the data to the ground. Four output ports of each APS are routed to the other APS electrical power port. Any one of the 44 incoming optical signals may be routed to any one of the 36 outgoing user ports. Up to 20 simultaneous connections may be supported. Each input can only connect to one output at a give time.

4.4.4 LOW RATE DATA LINK SYSTEM

The Payload MDM coordinates all LRDL communication (see Table 4.4.5–1) to and from the payloads via four MIL–STD–1553B Payload Local buses (known as LRDL). Each of the four external buses is a single redundant MIL–STD–1553B Data Bus that has one bus controller (Payload MDM) with two physical sets of wiring. Payloads on the USOS external Attached Payload sites use two payload local buses, LB PL–1 (S3 segment) and LB PL–2 (P3 segment).

Payloads on the International Partner sites use local bus LB PL–JEM (JEM Exposed Facility) and ESA PL–BUS (Columbus External Payload Facilities)

The Payload MDM receives an aggregate of 1,392 Kbps from the four local busses which is sent via the HRDL to the Ku–band system.

4.4.5 HIGH RATE DATA LINK

The C&DH HRDL provides high rate data transfer (see Table 4.4.5–1) from payload locations in the US truss attach sites to the C&T system for downlink. Also, high rate payload–payload communication is provided between all US Attached Payload sites. Payloads are to use internet based protocols, i.e. TCP/IP, for this kind of data. High rate communications are provided via fiber optic lines through the APS, a remotely configurable patch panel. Since, the patch panel is electronic, the crew cannot change any fiber optic connection manually. The HRDL is a point to point data link. The data rate between a payload site and another payload site can be set to 100 Mbps. The HRDL has four fiber optic input/four fiber optic output connections at the S3 segment and two fiber optic input/two fiber optic output connections at the P3 segment.

As shown in Figure 4.4–2, the High Rate Frame Multiplexer (HRFM) combines the data from eight HRDL sources and four video channels, and transmits a 50 Mbps data stream to the High Rate Modem (HRM) of the Ku–band system.

TABLE 4.4.5–1 DATA LINK CAPABILITIES

ISS Program Name	Parent Industry Data Link	Data Rate	Throughput Rate	Baud Rate	Signaling Rate	Encoding Scheme	Media Access
HRDL	FDDI PHY based	100 Mbps	50 Mbps	125 Mbps	62.5 MHz (max)	FDDI PHY	Scheduled through the APS
LRDL	MIL–STD–1553B	1 Mbps	750 Kbps	1 Mbps	2 MHz	Bi–Phase L	Scheduled

4.5 ENVIRONMENTS

The presence, operation, and motion of the ISS will affect the surrounding external environment. The Attached Payload Developer should be aware of the potential effects of both natural and induced environments, the limiting or boundary environmental conditions established for design values, and other environmental concerns/requirements for ISS payload configurations.

4.5.1 ISS FLIGHT ATTITUDES

Attached Payloads must be able to remain safe while in each of the ISS orbital attitudes as defined in Table 4.5.2–2.

4.5.2 THERMAL

The Attached Payload will be exposed to thermal solar constants, earth albedo, and earth Outgoing Long–wave Radiation (OLR) environments as defined in Table 4.5.2–1; a space sink temperature of 35K; the induced thruster plume environment and induced thermal environments from vehicle(s) docking and while docked with the ISS; and thermal interactions with other on–orbit segments. Induced thermal effects on Attached Payloads due to beta angle extremes, orbital altitude, and attitude variation about the ISS vehicle axes are provided in Table 4.5.2–2.

TABLE 4.5.2–1 HOT AND COLD NATURAL THERMAL ENVIRONMENTS

Case	Solar Constant (W/m^2)	Earth Albedo	Earth Outgoing Long Wave Radiation (W/m^2)
Cold	1321	0.2	206
Hot	1423	0.4	286

TABLE 4.5.2–2 INDUCED THERMAL ENVIRONMENTS

Induced Environment	Assumed Parameters
Beta Angle	+/– 75°
Altitude	150 nmi. to 270 nmi.
Attitude Envelope Without Orbiter (1)	Any combination of +/–15° Roll (about X axis) (2) +/–15° Yaw (about Z axis) (2) +15 to –20° Pitch (about Y axis) (2)
Attitude Envelope With Orbiter Docked to ISS (1)	Any combination of +/– 15° Roll +/– 15° Yaw 0 to 25° Pitch

Note(s):

1) The attitude variations include variations in the Torque Equilibrium Attitude (TEA) as well as variations in the ISS attitude from the TEA attitude, both with Orbiter docked, and without Orbiter.

2) XYZ axes refer to ISS coordinate system orientation.

4.5.3 PRESSURE

The Attached Payload will be exposed to an on–orbit minimum pressure environment of 1.93E–09 psia (1.0 x 10E–07 Torr).

4.5.4 HUMIDITY

The Attached Payload will be exposed to a relative humidity of 0 percent while on orbit.

4.5.5 EXTERNAL CONTAMINATION

Contamination is present to some extent in all environments in the form of particles, molecular films or gases, and organisms. ISS external surfaces continually outgas and shed particles. Some ISS operations such as venting and destruction/elimination of trash can be highly contaminating. All of these contaminating aspects of the ISS will be predicted, controlled, or minimized to prevent adverse effects on the ISS hardware, payloads, and crew. Payloads should be designed to minimize the possibility of external contamination through containment of destructive materials and proper material selection.

Contamination accumulation on hardware is determined by the exposure level in a particular phase and the duration of exposure in that phase. When contamination accumulation may result in system degradation, protective measures by the Attached Payload Developer such as covers, periodic cleaning, or operational precautions may be required.

The Attached Payload will be exposed to the external contamination environments as specified in SSP 30426, External Contamination Control Requirements, paragraphs 3.4 and 3.5.

4.5.6 ATOMIC OXYGEN

The Attached Payload will be exposed to an average Atomic Oxygen (AO) flux of 5.0 x 10E21 atoms per cm^2 per year for the on–orbit exposure duration.

Surfaces exposed 30 days or less will be exposed to an average 4.4 x 10E19 atoms per cm^2 per day.

4.5.7 ELECTROMAGNETIC RADIATION

The Attached Payload Electromagnetic Radiation environment is specified in SSP 30243, Space Station Requirements for Electromagnetic Compatibility, paragraph 3.2.3, including applicable references.

4.5.8 PLASMA

The Attached Payload will be exposed to the on–orbit natural plasma environment as specified in SSP 30425, Section 5.0, and the induced plasma environment as specified in SSP 30420, Space Station Induced Plasma Environment, paragraph 3.3. The difference between the Attached Payload structure floating potential and the local plasma field potential does not exceed +/–40 volts.

4.5.9 IONIZING RADIATION

Attached Payloads are exposed to ionizing radiation and will accumulate total dosage dependent on location and shielding. Shielding provided by adjacent payloads may be considered in calculating total radiation dose exposure. Information on radiation dosage rates may be found in SSP 30425.

4.5.10 SINGLE EVENT EFFECT IONIZING RADIATION

Equipment exposed to ionizing radiation may be subject to Single Event Effect (SEE), a generalized category of anomalies that result from a single ionizing particle. This term includes such effects as single event upsets, transients, latchup, permanent upset, and device burnout effects. SEE analysis is performed per SSP 30512.

4.5.11 SOLAR ULTRAVIOLET RADIATION

The Attached Payload will be exposed to on–orbit solar ultraviolet radiation environment as specified in SSP 30425, paragraph 7.2

4.5.12 PLUME IMPINGEMENT

Attached Payload and externally exposed secondary structure (e.g. Multi–Layer Insulation (MLI) blankets) will be exposed to the maximum effective normal and shear plume impingement pressures defined below:

A. Normal pressure 3.42 psf

B. Shear pressure 0.80 psf

4.5.13 METEOROIDS AND ORBITAL DEBRIS

The Attached Payload will be exposed to the M/OD environments as specified in Section 3.4.1.5. Parameters of ISS M/OD environments definition are given in Table 4.5.13–1.

TABLE 4.5.13–1 PARAMETERS FOR M/OD ENVIRONMENTS DEFINITION

Altitude	215 nautical miles (400 km)
Orbital inclination	51.6 degrees
ISS attitude	LVLH 10% of the time (Orbiter attached) TEA 90% of the time (Orbiter not attached)
Solar flux	70 x 10^4 Jansky ($F_{10.7}$ – 70)
Orbital debris density	2.8 gm/cm^3
Maximum debris diameter (1)	20 cm
Note: (1) High degree of confidence of collision avoidance for this size and larger orbital debris objects.	

4.5.14 ACCELERATION

4.5.14.1 ON–ORBIT ACCELERATION ENVIRONMENT

A. The AP/UCC will meet structural integrity requirements in an on–orbit acceleration environment having peak transient accelerations of up to 0.2 g's, a vector quantity acting in any direction. This criteria is to be used as a component load factor and assumes that the payload mass and center of gravity are within the envelope defined in 3.1.3.1.2.2. This acceleration is not intended to be used to calculate interface loads.

B. During payload installation, the AP/UCC will meet structural integrity requirements having peak transient accelerations of up to 0.4 g's, a vector quantity in any direction. This criteria is to be used to assess the effects of the impact during payload installation. This acceleration is not intended to be used to calculate interface loads.

4.6 MATERIALS, PROCESSES, AND PARTS

Materials, processes, and parts used in fabricating payload hardware are selected by considering operational requirements for a particular application and the design engineering properties of candidate materials. Operational requirements to be considered include, but are not limited to, operational temperature limits, loads, contamination, life expectancy, and vehicle related induced and natural space environments. Properties to be considered in material and parts selection include mechanical properties, fracture toughness, flammability, offgassing characteristics, corrosion, stress corrosion, thermal and mechanical fatigue properties, vacuum outgassing, and fluids compatibility.

4.6.1 MATERIALS AND PARTS USE AND SELECTION

Materials and parts used in Attached Payload hardware and equipment must comply with the safety requirements in NSTS 1700.7 ISS Addendum, Safety Policy and Requirements for Payloads Using the International Space Station, paragraphs 208.3 and 209, with the exception of the toxic offgassing requirements of paragraph 209.3. This includes commercial and “off–the–shelf” parts except conformally coated EEE parts; however, conformal coating material must comply. Material selected is based on design criteria, using those listed in the Materials and Processes Technology Information System (MAPTIS) database, administered by Marshall Space Flight Center (MSFC), and MSFC–HDBK–527/JSC 09604, Materials Selection List for Space Hardware Systems, handbook that are “A” rated in their use environment. For Attached Payloads, the environment for flammability considerations will be air at 14.7 psi. The use of non “A” rated materials as defined in MSFC–HDBK–527/JSC 09604 handbook or the MAPTIS database, requires submittal of a Materials Usage Agreement (MUA) to a NASA Materials Application and Evaluation Board (MAEB) for approval. The MAEB may request that samples of non–rated materials be submitted for testing.

From Phase I lessons learned, it is suggested that attached payload developers provide a complete list of all the materials that may be used in developing hardware, even “second choice” materials, during the safety process. By providing a list which includes “second choice” materials, all materials, including substitute materials, will be analyzed and acceptable materials approved during the normal process. This will save work and speed the process should a “first choice” material be unavailable during construction requiring substitution late in the design.

4.6.2 ELECTRICAL, ELECTRONICS, AND ELECTROMECHANICAL PARTS FOR UMA

Electrical, Electronics, and Electromechanical (EEE) parts must be selected from SSP 30312, Electrical, Electronic, and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program, and SSP 30423, Space Station Approved EEE Parts List, and are derated per criteria covered in SSP 30312. Nonstandard EEE parts, not listed in SSP 30423, must be qualified per qualification requirements of SSP 30312.

4.6.3 CLEANLINESS

Attached Payload hardware external surfaces must be cleaned to comply with Visibly–Clean Standard (VC–S) as specified in SN–C–0005, NSTS Contamination Control Requirements Manual.

4.7 EXTRAVEHICULAR ROBOTICS

The robotics systems of the ISS are used in ISS assembly and maintenance, as well as EVA support and payload handling. This document describes the Mobile Servicing System (MSS) as the primary robotics system used to support ISS Attached Payloads. Attached Payloads use of the Shuttle Remote Manipulator System (SRMS) support will also be discussed.

The Canadian Space Agency (CSA) and NASA are working together in the development of the MSS which has five subsystems. CSA is responsible for the SSRMS, the Mobile Remote Servicer Base System (MBS), and the Special Purpose Dexterous Manipulator (SPDM). The other two MSS subsystems, the Mobile Transporter (MT) and the Robotic Workstation (RWS), are the responsibility of NASA.

4.7.1 EQUIPMENT REQUIRING SHUTTLE ROBOTIC SUPPORT

Attached Payloads will normally be removed from the Space Shuttle payload bay using the SRMS. The SSRMS grapples the Attached Payload using a second payload mounted grapple fixture. After the SRMS releases its grasp of the payload, it is parked in a safe configuration allowing further robotics activities involving payloads, vehicle, or EVA crew. An Attached Payload requiring SRMS support will be in accordance with SSP 57003, paragraph 3.7.1.

4.7.2 MOBILE SERVICING SYSTEM

Payload transfer operations at the ISS will be handled robotically. This will minimize exposure of crewmembers to the external environment and conserve resources. The Mobile Servicing System (MSS) is used for unloading payload carriers from the Earth–to–orbit transport vehicle and for transferring Attached Payloads to truss sites.

It is recommended that SSP 42004, Mobile Servicing System to User (generic) Interface Control Document, be referred to for definition and control of the physical and functional interfaces which shall be provided by the MSS for Attached Payloads.

Figure 4.7.2–1 displays the external components of the MSS, as well as the Robotic Workstation (RWS), the only internal component.

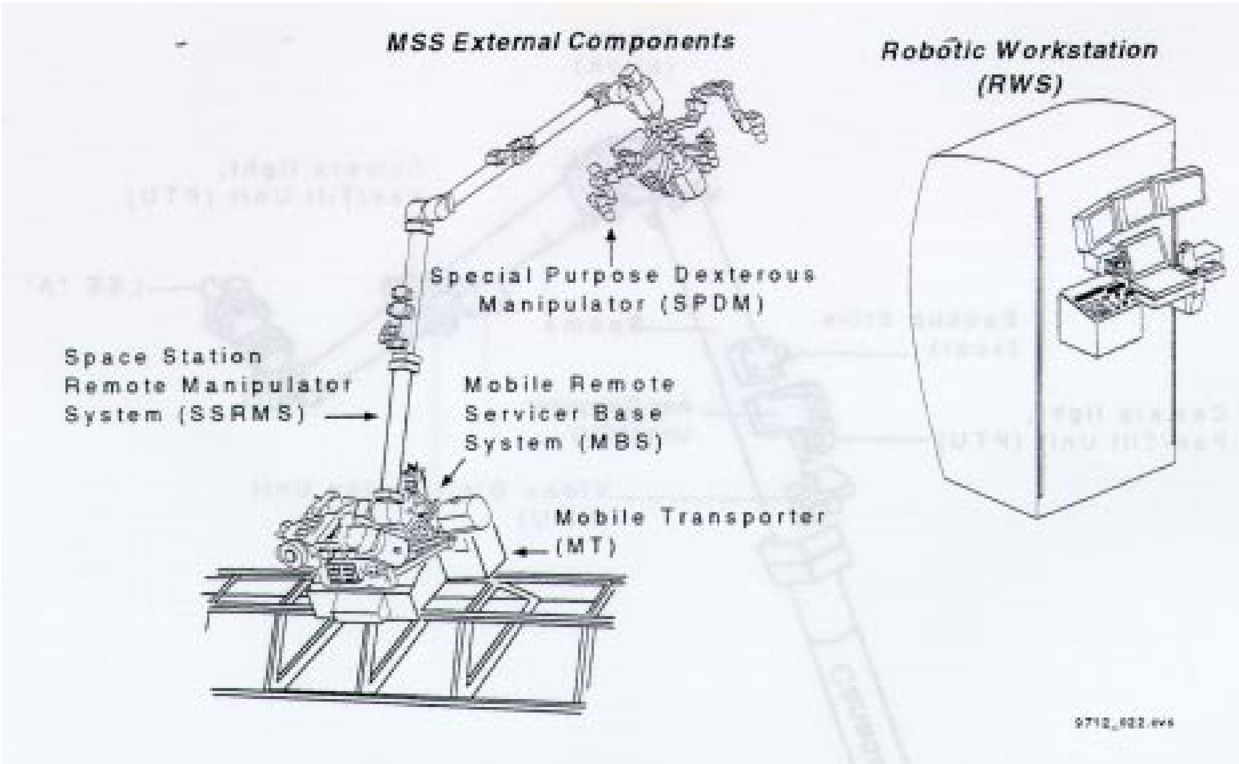


FIGURE 4.7.2–1 OVERVIEW OF MOBILE SERVICING SYSTEM

4.7.3 SPACE STATION REMOTE MANIPULATOR SYSTEM

One of the first MSS subsystems to arrive on the ISS is the SSRMS. It is used to handle large payloads and ORUs. Tasks include berthing and unberthing, maneuvering, and performing hand–offs with other robotics systems. The SSRMS, illustrated in Figure 4.7.3–1, is also able to position the SPDM at worksites, provide EVA support and perform ISS external inspection. Other capabilities include free–flyer capture and Orbiter berthing (unplanned).

The SSRMS is a 56–ft (17–m) symmetric manipulator that supports electronic boxes and video cameras. It is composed of several ORUs, including two Latching End Effectors (LEEs), two booms, and seven joints that can be rotated +/– 270°. A LEE at each end of the SSRMS creates a ”walking” capability between attach points called Power and Data Grapple Fixtures (PDGFs). This “walking” ability is the only mode of transportation for the SSRMS prior to the arrival of the Mobile Transporter (MT) and the MBS. A LEE is shown in Figure 4.7.3–2.

The SSRMS uses more than one type of grapple fixture on the ISS. One type, the PDGF provides power, data and video connections to the arm. The PDGF, illustrated in Figure 4.7.3–3, is the only interface from which the arm can operate. These grapple fixtures are located throughout the ISS and provide interfaces to other elements and payloads.

An Attached Payload which requires SSRMS support will interface with the LEE by using the PDGF, or a Flight Releasable Grapple Fixture (FRGF), or a Power Video Grapple Fixture (PVGF) in accordance with SSP 57003, paragraph 3.7.3.

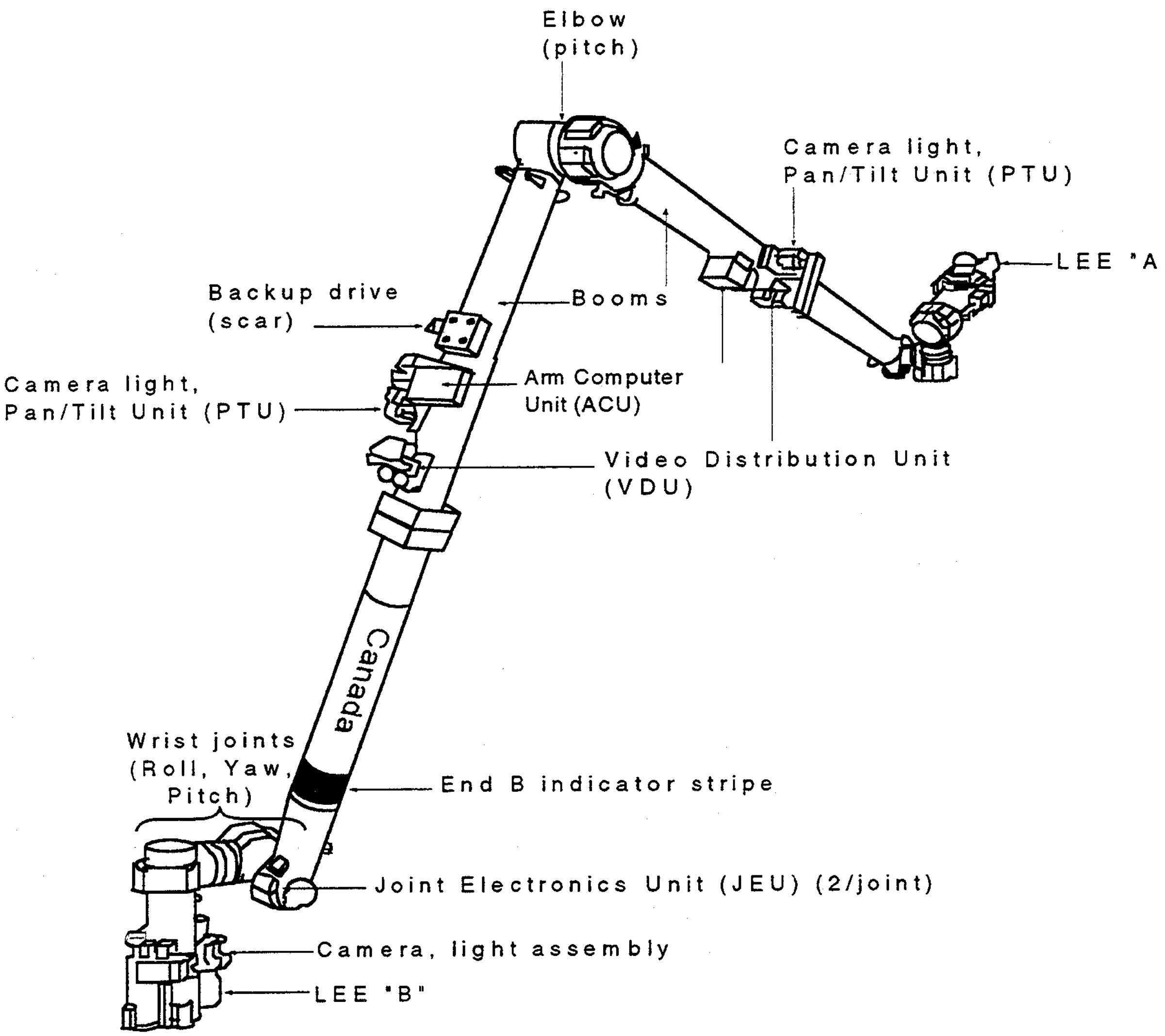


FIGURE 4.7.3–1 SPACE STATION REMOTE MANIPULATOR SYSTEM

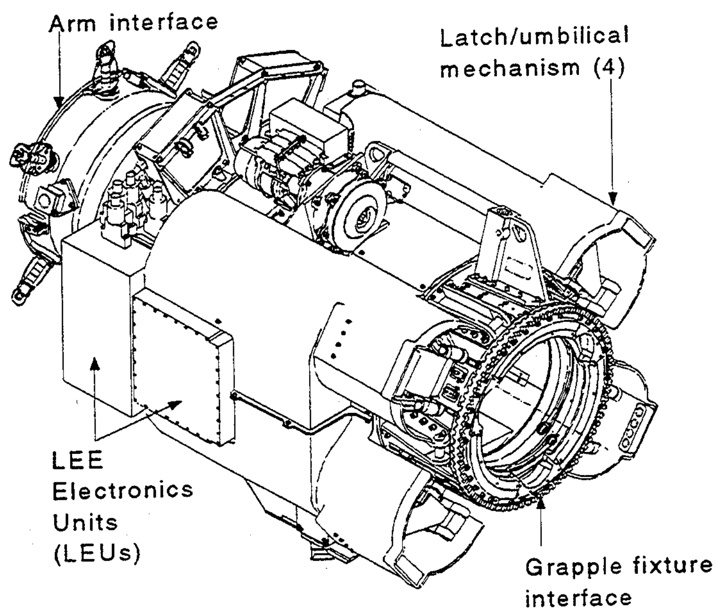


FIGURE 4.7.3–2 LATCHING END EFFECTOR

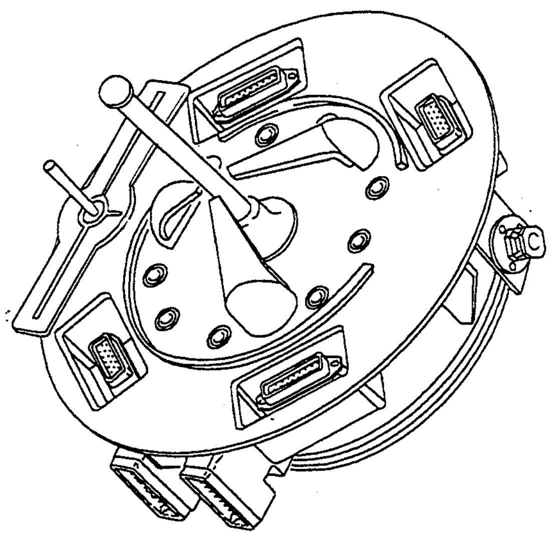


FIGURE 4.7.3–3 POWER AND DATA GRAPPLE FIXTURE

4.7.4 MOBILE TRANSPORTER

The MT shown in Figure 4.7.4–1 provides structural, power, data, and video links between the ISS and the MBS. It also provides transportation for the SSRMS, SPDM, payloads, and even EVA crewmembers. At its greatest velocity (1 inch/sec), the maximum automated translation time is 50 minutes from one end of the truss to the other. When the MT is transporting large payloads across the Station, there can be an impact to the Guidance, Navigation and Control (GNC) System due to the changing mass properties of the ISS. If the Control Moment Gyros (CMGs) are unable to handle the change in momentum, jets may be fired to compensate for the change.

Operator interface for the MT is through a PCS Graphical User Interface (GUI) that can be located either at the RWS or connected to another PCS port. Since no switches are needed, total control from the ground is possible, although ground control capability is primarily for powerup and system checkout. The communication interface is given by the Trailing Umbilical System (TUS). The TUS transfers commands from the MT and data from the MBS when at a worksite. It also allows the MBS to send video to the truss. The power interface for the MT is also provided by the TUS, while the MBS receives power through the UMA. After the MT arrives at a utility port worksite, it locks itself down and connects the UMA so it can send power to the MBS.

An Attached Payload requiring robotic translation support must be in accordance with SSP 57003, paragraph 3.7.5.

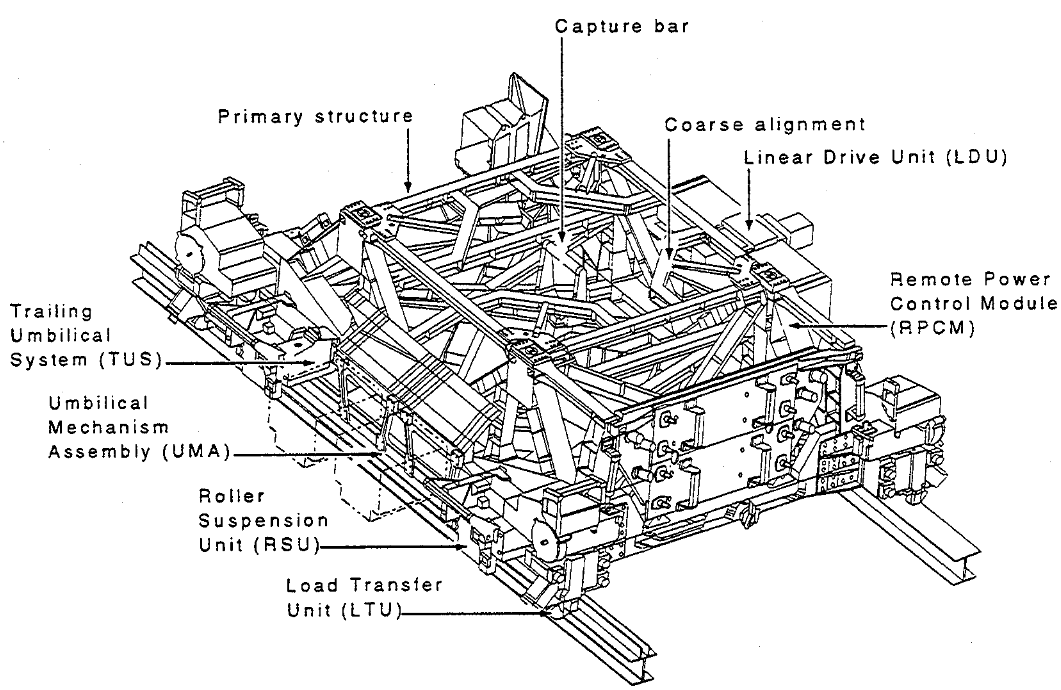


FIGURE 4.7.4–1 MOBILE TRANSPORTER

4.7.5 MOBILE REMOTE SERVICER BASE SYSTEM

Another component of the MSS is the MBS shown in Figure 4.7.5–1. Since the MBS is an interface between the SSRMS, SPDM, ORUs, payloads, EVA and the MT, the MT cannot transport anything until the MBS is affixed to the MSS. It functions both as a work platform and as a base for the SSRMS.

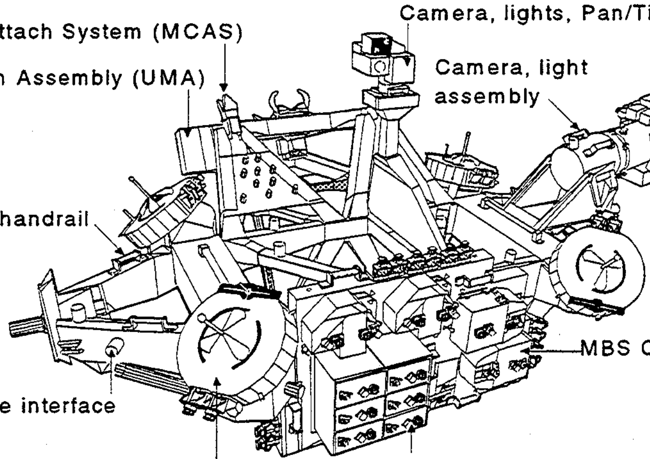


FIGURE 4.7.5–1 MOBILE REMOTE SERVICER BASE SYSTEM

Control of the MBS is accomplished by the Robotic Workstation (RWS). Similar to the rest of the MSS subsystems, the MBS has redundancy built in. Like the SSRMS, the MBS has dual electrical and electromechanical systems.

4.7.6 SPECIAL PURPOSE DEXTEROUS MANIPULATOR

The SPDM shown in Figure 4.7.6–1 is the final component of the MSS to arrive on the ISS. It is composed of two 11.5–ft (3.5–m) seven–joint arms attached to a central single–joint body structure. These joints enable the dexterity of this system.

Due to this manipulator's ability to execute dexterous operations, its primary function is to perform maintenance and payload servicing. SPDM can assist EVA by transporting and positioning equipment. Control for this manipulator is provided through the RWS with control modes and features common to the SSRMS. Only one SPDM arm may be used at a time; the other arm can be used for stabilization at a worksite.

An Attached Payload requiring dexterous robot support must be designed in accordance with SSP 57003, paragraph 3.7.4.

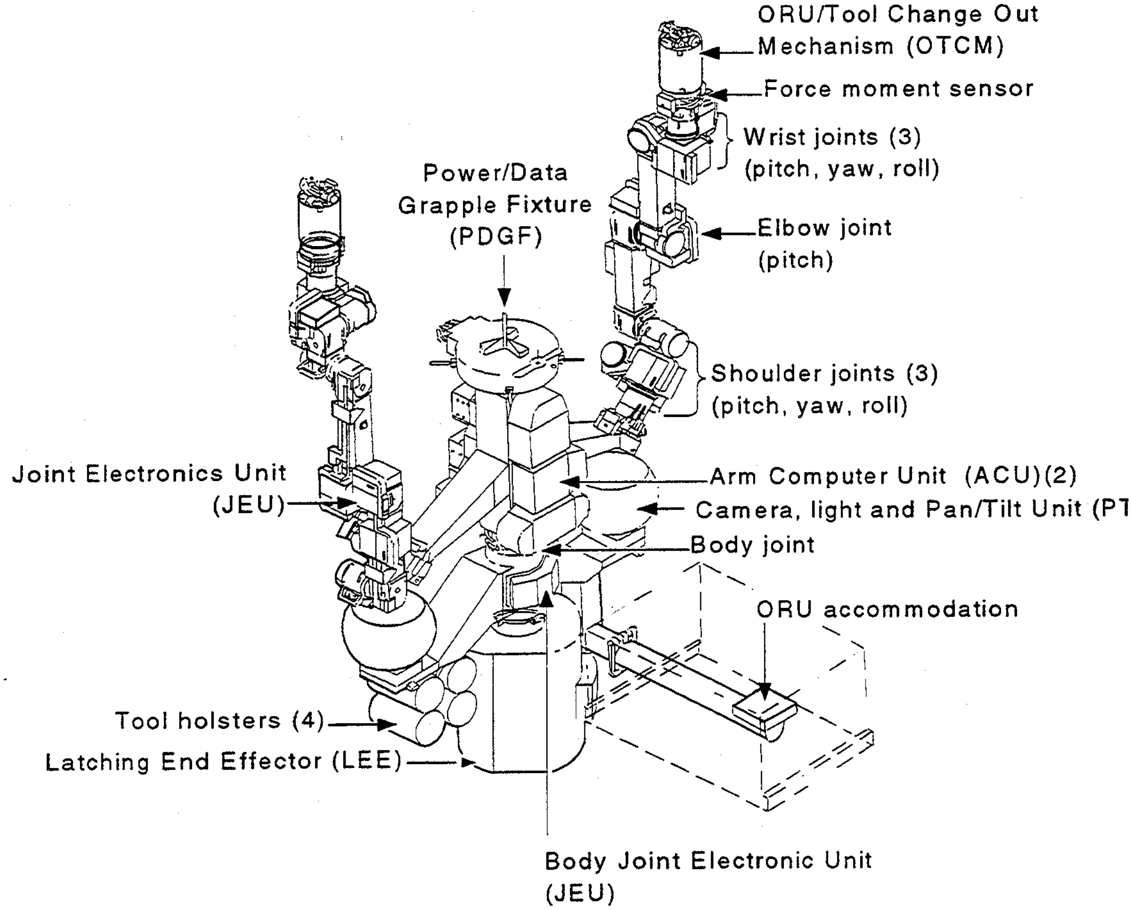


FIGURE 4.7.6–1 SPECIAL PURPOSE DETEROUS MANIPULATOR

4.7.7 SUMMARY OF ROBOTIC SYSTEMS AND SUBSYSTEMS

This subsection describes the tasks each robotic system performs for Attached Payloads and how they perform them, what kind of control system is used, and what the system capabilities are. Table 4.7.7–1 summarizes the robotics systems/subsystems, who is responsible for each, and the different prime functions. It is important to remember that to accomplish required robotics tasks, the robotics systems need the coordinated help of other ISS systems, including GN&C, C&T, Electrical, C&DH, as well as the crew and the ground.

TABLE 4.7.7–1 SUMMARY OF ROBOTICS SYSTEMS AND SUBSYSTEMS

Robotic Component	International Partner	Prime Function(s)
SSRMS	CSA	Assembly, maintenance, payload handling, and EVA support
RWS	NASA	Operator interface to SSRMS, MBS, and SPDM
MT	NASA	Transportation of MBS, SSRMS, SPDM, EVA, payloads and ORUs
MBS	CSA	Work platform and an interface to MT
SPDM	CSA	Maintenance and payload servicing

4.8 EXTRAVEHICULAR ACTIVITY

4.8.1 TYPES OF EXTRAVEHICULAR ACTIVITIES

For ISS, there are two types of EVAs: nominal and contingency. For Attached Payloads, only contingency EVA is available.

4.8.2 EXTRAVEHICULAR ACTIVITY AIDS

The ISS provides EVA aids to assist EVA crewmembers in the assembly, contingency operations, and maintenance of the ISS. The EVA aids are used at worksites and along translation paths to restrain the EVA crewmembers, to provide stable work platforms, and to perform contingency and maintenance operations.

4.8.3 EXTRAVEHICULAR ACTIVITY AS A BACKUP FOR ROBOTICS ACTIVITIES

The Attached Payload is designed such that all operations are performed via EVR, with contingency EVA capability. While EVR is primary for Attached Payloads, the payload developer will provide the hardware, translation paths, and appropriate labeling to affect EVA access to the Attached Payload hardware in accordance with SSP 50005, International Space Station Flight Crew Integration Standard (NASA STD 3000/T) Document, and SSP 30256, Extravehicular Activity Standard Interface Control Document, in the event that contingency operations are needed.

4.8.4 HUMAN FACTORS

Attached Payloads must be designed to accommodate the human interface for EVA contingency activities. Reference JSC–20466, EVA Tools and Equipment Reference Book, and SSP 50005 for EVA tools/restraints for additional data. Table 4.8.4–1 provides several design considerations for the Attached Payload which will enable contingency EVA operations.

TABLE 4.8.4–1 HUMAN FACTORS DESIGN CONSIDERATIONS

DESIGN CONSIDERATION	DESCRIPTION
Access	• Payload hardware must be geometrically arranged to provide physical and visual access. • Must not require the removal of another ORU or more than one access cover. • Equipment must remain in the ”open” position without being supported by hand.
Nonpressurized Area Equipment Maintenance Time	• Maintenance tasks must be divided into subtasks and be completed in a single EVA sortie of less than three hours. • Worksite maintenance tasks exceeding three hours must be partitioned into subtasks, of less than three hours, and the task resumed on a succeeding EVA.
Captive Parts	All parts (i.e., knobs, handles, covers, access plates, or similar devices) that may be temporarily removed on orbit will be tethered or otherwise held captive.
Installation/Removal Method	The gloved hand alone or common hand tools will be used to install/remove items.
Equipment Item Interconnecting Devices	Remove/replace items must provide utility line attachment/mounting length to allow removal/replacement of equipment item.
Incorrect Equipment Installation	Physical provisions (a structural or mechanical barrier) are to be used to preclude incorrect installation of equipment.
Lockwiring and Staking	Maintenance equipment installations or operational interfaces may not be lockwired or staked. Lockwiring is prohibited in areas accessible by the EVA crewmember.
Restraining and Handling Devices for Temporary Storage	• Equipment must accommodate restraining and handling by EVA crew to provide temporary storage. • Provisions must allow for restraining and handling equipment by robotic devices to provide for temporary storage.
Installation/Removal Force	Capture–type receptacles that require a push–pull action must be activated with a force less than 156 N (35 lbf).
Direction of Removal	Items must be removed along a straight path until they have cleared the surrounding structure.
Visibility	All edges of equipment must be visible during alignment and attachment.
Mounting Alignment	• Equipment must be designed, labeled, or marked to facilitate proper installation. • When alignment marks are used, they will be applied to both mating parts. • Electrical connectors must have provisions for alignment and mating of connector shells prior to electrical path completion.

TABLE 4.8.4–1 HUMAN FACTORS DESIGN CONSIDERATIONS

DESIGN CONSIDERATION	DESCRIPTION
CLA and UMA Extravehicular Activity Manual Override	EVA access for CLA and UMA manual override must be provided.
Payload Attach System – Passive	• An EVA releasable and removable capture must be provided. • EVA access to the passive UMA must be provided.
Attached Payload Remove/Replace Items	Remove/replace items designed for dexterous robotic manipulation must be maintainable by EVA.
Extravehicular Activity Tools	Inspection, remove/replace, and maintenance tasks are to utilize the tools provided by the ISS per SSP 30256:001, Tables 3.2–1 and 3.2–2.
Tool Clearance	• Equipment and structures surrounding bolts requiring EVA ratcheting must allow a 90 degree throw angle and allow right or left handed operations. • A 3 inch clearance for EVA gloved–hand access around the tool handle must be provided.
Payload Hardware and Equipment Mounting	• Hardware must be designed, labeled, or marked to prevent improper installation • Alignment marks must be consistent and on both mating parts.
One–Handed Operation	• All connectors, whether operated by hand or tool, must be mated/demated using one hand. • Connector design and placement must accommodate either the right or the left hand.
Mate/Demate	Connectors must be mated/demated without having to remove or mate/demate other connectors. Mating/demating of electrical connectors must conform to the requirements of NSTS 18798, Payload Safety Requirements, interpretation letter MA2–99–170, Crew Mating/Demating of Powered Connectors.
Connector Arrangement	• Space between connectors and adjacent obstructions must have a minimum of 1.6 inches to enable EVA access. • Connectors in a single row or staggered rows which are removed sequentially by the crew must have 1.6 inches of clearance from the other connectors and/or adjacent obstructions for 270 degrees of sweep around each connector beginning at the start of a removal/replacement sequence.
Status	Connector mating status must be provided.
Connector Protection	Protection is to be provided for all demated connectors against physical damage and contamination.
Protecting Caps	All connector protective caps must be tethered.
Coding	• A code or identifier unique to that connection is to be provided on both halves of mating connectors. • Labels or codes on connectors must have locations so they are visible when connected or disconnected.

TABLE 4.8.4–1 HUMAN FACTORS DESIGN CONSIDERATIONS

DESIGN CONSIDERATION	DESCRIPTION
Pin Identification	Each pin must be identified in each electrical plug and each electrical receptacle.
Orientation	Grouped plugs and receptacles will be oriented so that the aligning pins will be in the same relative position.
Spacing	Where wing connectors are used, the minimum clearance between adjacent wing tabs must be 2.5 inches.
Cable Restraints	• Loose ends of cables must be restrained. • Cables with connectors that may be mated/demated on orbit are to be restrained at the ends by EVA compatible clamps to facilitate EVA maintenance operations. • Cables, conductors, or bundles are to be secured by means of clamps unless they are contained in wiring ducts or cable retractors. • Cables can be bundled if multiple cables are running in the same direction.
Covers	• Access covers are to be provided when routine maintenance operations would otherwise require removing the entire case or cover, or dismantling an item of equipment. • Closures may be removable to allow maintenance of equipment. • Closures are to have a positive means of indicating that they are locked. • Nonstructural closures need to be capable of sustaining EVA–induced loads as specified in SSP 57003, Table 3.1.3.1.9.5.1–1. • Bulkheads, brackets and other units may not interfere with removal or opening of covers. • Access covers that are not completely removable are to be self–supporting in the open position. • Equipment housings (i.e., electrical bays) are to be able to provide closures and covers for inaccessible areas. • Inaccessible areas are to be sealed to prevent any loose item from drifting into them.
Fastener Engagement Status Indication	• EVA actuated fasteners/devices will be visually accessible to ensure proper seating or restraint in stowed or installed locations. • An indication of engagement is to be provided in stowed or installed locations.
One–Handed Actuation	All fasteners must be actuated by one of either the right or left hand.

TABLE 4.8.4–1 HUMAN FACTORS DESIGN CONSIDERATIONS

DESIGN CONSIDERATION	DESCRIPTION
Fastener Clearances	• A 3.0 inch clearance between a tool handle engaged on a fastener or drive stud and the nearest piece of hardware must be maintained through a full 180 degree sweep envelope. For a driver–type tool, clearance is to be maintained through 360 degrees. • Clearance between the fastener and the robotic interface must allow for insertion, actuation, and removal of the drive end of a standard tool.
Fastener Access Holes	Covers or shields will have holes for passage of the fastener without precise alignment.
Captive Fasteners	• Fasteners will be captive or have special provisions to restrain the fasteners. • Hardware will preclude the use of temporary fasteners.
Quick Release Fasteners	• Quick release fasteners are to have a maximum of one complete turn to operate (quarter–turn fasteners are preferred). • Quick release fasteners are to be positive locking in open and closed positions.
Over Center Latches	• Undesired latch realignment, interface, or reengagement will be prevented. • Latch catches will have locking features. • If the latch has a handle, the latch handle and latch release must be operable by one hand.
Fastener Heads and Knobs	• Fasteners and knobs for suited gloved hand operation must have a minimum head diameter of 1.5 inches and a maximum diameter of 2 inches. • Fasteners and knobs are to have a minimum head height of .75 inches.
Contingency Override	• A standard–sized internal or external hexagonal feature must be provided for contingency override with a hand tool. • Cotter keys may not be used by EVA.
Contingency Extravehicular Activity Controls	• Switches must provide tactile and/or visual indication of position. • EVA controls must be protected from inadvertent actuation.
Displays	EVA displays are to be located within the field of view permitted by the EMU.
Labeling	Labeling and color coding at EVA workstations must conform to SSP 50005, paragraph 9.5.

4.9 MAINTAINABILITY AND MAINTENANCE

Attached Payload facility hardware and software may be designed to be maintainable to allow functions to be reinstated or restored throughout its intended operational life. Attached Payloads which are not designed to be maintained will not be required to meet the requirements of SSP 57003, Section 3.9.

4.9.1 DEFINITIONS

Maintainability: The measure of the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance. It is the inherent characteristics of a design or installation that contribute to the ease, economy, safety, and accuracy with which maintenance actions can be performed, and is implemented most effectively prior to or during design and manufacture. Maintainability also includes the ability to perform corrective or preventative maintenance within required limits.

Maintainability Engineering: The engineering discipline which formulates an acceptable combination of design features, repair policies and maintenance processes, to achieve a specified level of maintainability, as an operational requirement at optimum life–cycle cost. It is a discipline which requires research, education and an emphasis on information exchange in all phases of system life, starting with the conceptual phase. It applies scientific knowledge and engineering skills to the development of items of equipment, to provide an inherent capability to be maintained (i.e., the possession of favorable maintenance characteristics). Maintainability engineering must be integrated with the other elements of system engineering to provide the necessary effectiveness, considering all costs over the entire life–cycle of the item.

Maintenance: All actions necessary for retaining an item in or restoring it to a specified condition. Maintenance refers to those activities actually performed upon an item to prevent failure, or in the event of failure, to restore it to a satisfactory level of operation. Maintenance, therefore, relates primarily to support of an item after it is in the hands of the user.

Orbital Replacement Unit (ORU): An item which can be removed from a system and replaced as a unit at the organizational on–orbit level of maintenance.

4.9.2 DELETED

4.9.3 ON–ORBIT MAINTENANCE

The purpose of this section is to provide the nomenclature, philosophy, and strategy (i.e., interfaces, accommodations and constraints) of On–Orbit Maintenance (OOM).

4.9.3.1 ISS MAINTENANCE PHILOSOPHY

Several unique factors of ISS, relative to previous U.S. space vehicles, have influenced the ISS philosophy of maintenance. The first factor is that the ISS is to remain permanently in space. Since the ISS is designed to operate for many years, all repairs must be designed to be permanent.

Another unique aspect of the ISS is that the entire vehicle is assembled in orbit. The zero–g environment of space causes special problems for crewmembers. Tools and loose ORUs have to be tethered and small parts restrained. Crewmembers have to determine the best method of anchoring themselves while they attempt to remove and replace defective ORUs and parts. In the Intravehicular Activity (IVA) environment, particles of debris caused by assembly or maintenance operations have to be collected and disposed of so they do not contaminate the crew's environment.

Finally, the lack of comprehensive end–to–end testing of the ISS components carries a great deal of potential for subsequent problems. Ideally, all of the ISS modules and trusses should be assembled on the ground, the mechanical and electrical interfaces between the various modules and trusses tested, and any problems repaired. The vehicle is then disassembled and the components carried into orbit by various launch vehicles. In the ISS program, the testing of interfaces between two mating modules cannot be carried out mainly because the hardware and software for the partner modules and elements are not available.

The major key to success for the ISS is timely and effective maintenance. The ISS program will be judged by the quality and quantity of science data produced, it is essential that the science–producing payloads remain operational as long as possible.

Critical ISS Vehicle replacement hardware components have been designed and developed to be replaceable as ORUs. Each ORU is considered critical to the overall success of the ISS or the safety of the vehicle or crew. Payloads are to be developed with simplicity and low maintenance in mind. Crewtime is limited and EVA operations are hazardous. The cost of implementing EVA compatible design can be significant for both the payload developer and the ISS, hence EVA maintenance tasks are required to be contingency only.

4.9.3.2 ON–ORBIT MAINTENANCE PHILOSOPHY

The ISS OOM philosophy is to use available resources to maintain, repair and replace failed ISS hardware components (e.g. ORUs) with the goal of returning the affected systems to their original configuration and efficiency.

4.9.3.3 TYPES OF ON–ORBIT MAINTENANCE

The following categories of maintenance are based on either the urgency of the maintenance, the time frame, or the place the maintenance will be carried out.

- Preventive – End item ORUs are to remain in a specified condition (i.e., retain end item functionality) by performing systematic inspection, detection, cleaning, repair, and/or replacement of parts at preplanned, specified intervals.
- Corrective – End item ORUs are restored to their original condition and maintenance can be performed by removal and replacement of equipment.
- In–Situ – End item repair and functionality is restored at the hardware site.
- Contingency – This on–orbit maintenance is performed to restore an end item function which is vital to crew safety or vehicle integrity. May require immediate action.

Based on the definitions above, there may be combinations of different types of maintenance.

4.9.3.4 ON–ORBIT MAINTENANCE STRATEGY

Attached Payload maintenance will be performed via EVR with EVA as a contingency back–up.

4.9.3.4.1 EXTRAVEHICULAR ACTIVITY TOOLS

The Attached Payload will be externally maintained utilizing the EVA tools listed in SSP 30256:001, Table 3.2–1, in the event of a contingency situation requiring EVA support.

4.9.3.4.2 ON–ORBIT MAINTENANCE BACK–UP

Attached Payload equipment that may be removed and replaced by robotics must have a back–up EVA remove and replace capability.

4.9.3.4.3 ACCESS FOR ON–ORBIT MAINTENANCE

The Attached Payload must provide access to all locations requiring on–orbit maintenance as specified in SSP 50005, paragraphs 14.6.2.3.A, 14.6.2.3.C, and 14.6.2.3.G.

4.9.3.4.4 STANDARD ON–ORBIT DIAGNOSTIC EQUIPMENT

Attached Payload ORUs designated for on–orbit maintenance will be maintained utilizing the diagnostic tools listed in SSP 30256:001, Tables 3.2–1 and 3.2–2.

4.9.3.5 LEVELS OF ON–ORBIT MAINTENANCE

The ISS program uses three levels of maintenance: organizational, intermediate and depot. Each succeeding level requires a higher level of skill and more complex tools and diagnostic equipment.

An ISS MDM can be used to illustrate the various levels of OOM. If a defective MDM is removed and replaced with a spare MDM, then organizational maintenance is being performed. If a defective MDM is removed, carried to the Maintenance Work Area, then intermediate level maintenance is being performed. If the defective circuit card is then carried to the ground where a failed integrated circuit chip on the card is replaced with a spare chip, then depot level maintenance is being performed.

4.10 SAFETY

ISS payloads must be able to demonstrate compliance with applicable safety requirements during all phases of a flight/mission. These requirements can be found in several sources, described in the following paragraphs. These documents establish the payload safety policy and requirements applicable to the Space Shuttle and ISS, including payload Ground Support Equipment (GSE). These documents are applicable to all new designs and existing designs (reflown and series) of Attached Payload hardware, during ground launch site processing, launch and return, and on–orbit operations.

Each payload developer is responsible for preparing safety compliance data packages for their hardware and operations, including establishing their own safety review schedule with the Payload Safety Review Panel (PSRP) based on payload hardware maturity. The results of these analyses are presented to the PSRP and become part of the payload complement safety certification.

Payloads which have a direct physical or functional interface with the Space Shuttle carrier and/or ISS elements or carriers must comply with the applicable requirements contained in the following documents:

A. NSTS 1700.7, Safety Policy and Requirements for Payloads Using the Space Transportation System, is the primary source document that establishes the safety policy and requirements applicable for payloads using the Space Transportation System. The requirements in this document are intended to protect flight and ground personnel, the Space Shuttle and other payloads, GSE, and the general public. The document contains technical and system safety requirements applicable to payloads which use the Space Shuttle.

B. NSTS 1700.7 ISS Addendum, Safety Policy and Requirements for Payloads Using the International Space Station, was prepared to expand and modify the existing NSTS 1700.7 requirements for payloads operating on or in the ISS. The addendum was created to relate unique ISS safety requirements to the users in a form that maintains continuity between the Shuttle and the ISS programs. The addendum identifies unique, ISS–only requirements and also indicates which NSTS 1700.7 requirements are applicable to both the Shuttle and ISS payloads. NSTS 1700.7 requirements that are not applicable to payloads during ISS operations are also indicated.

C. NSTS/ISS 18798, Interpretations of NSTS/ISS Payload Safety Requirements, is a series of letters and memos, based primarily on PSRP experience, designed to provide interpretation and/or additional guidance to payload organizations to help ensure understanding of and compliance with the existing requirements of NSTS 1700.7.

D. KHB 1700.7, Space Shuttle Payload Ground Safety Handbook, provides the ground handling safety policy and requirements for Space Shuttle (and ISS) payloads and portable GSE design and operations at the launch site. These requirements are applicable to ISS payloads from arrival at the launch site to lift–off, and during postlanding activities. This document establishes the minimum NASA ground processing safety policy, criteria, and requirements for ISS payloads and associated payload organization–provided GSE, including detailed safety requirements for ground operations and payload/GSE design not contained in NSTS 1700.7. KHB 1700.7 does not address facility GSE and non–ISS/STS program elements or flight safety.

E. NSTS 13830, Implementation Procedure for NSTS Payloads System Safety Requirements Document, defines the safety review process and assists the payload developer in implementing the system safety requirements of NSTS 1700.7. It describes the initial contact meeting with the payload organization and defines the subsequent safety reviews necessary to comply with the system safety requirements of NSTS 1700.7 and KHB 1700.7, which are applicable to payload design, flight operations, GSE design, and ground operations. NSTS 13830 also contains detailed instructions on payload safety analyses and safety data submittals which document the results of the analyses. The document has been revised to address ISS requirements and safety process improvements.

APPENDIX A
ABBREVIATIONS AND ACRONYMS

AC	alternating current
amps	Amperes
AMS	Alpha Magnetic Spectrometer
AO	Atomic Oxygen
AP	Attached Payload
APFR	Articulating Portable Foot Restraint
APPI	Attached Payload Port Interface
APS	Automated Payload Switch
ARPC	Auxiliary Remote Power Controller
C	Centigrade
C&DH	Command and Data Handling
C&C	Command and Control
C&T	Communications and Tracking
C&W	Caution and Warning
CETA	Crew and Equipment Translation Aid
cg	Center of Gravity
CLA	Capture Latch Assembly
CMG	Control Moment Gyros
COR	Communications Outage Recorder
CSA	Canadian Space Agency
dB	Decibel
dBm	Decibels referenced to One Milliwatt
dc	Direct Current
DDCU	Direct Current–to–Direct Current Converter Unit
EEE	Electrical, Electronic, and Electromechanical
EF	Exposed Facility
EMC	Electromagnetic Compatibility
EMU	Extravehicular Mobility Unit

EPCE	Electrical Power Consuming Equipment
EPS	Electrical Power System
ESA	European Space Agency
EVA	Extravehicular Activity
EVR	Extravehicular Robotic
ExP	EXPRESS Pallet
ExPA	EXPRESS Pallet Adapter
ExPCA	EXPRESS Pallet Control Assembly
ExPS	EXPRESS Pallet System
EXPRESS	Expedite the Processing of Experiments to Space Station
F	Fahrenheit
FRAM	Flight Releasable Attachment Mechanism
FRGF	Flight Releasable Grapple Fixture
GNC	Guidance, Navigation and Control
GPMCP	Generic Payload Microgravity Control Plan
GSE	Ground Support Equipment
GUI	Graphical User Interface
HRDL	High Rate Data Link
HRFM	High Rate Frame Multiplexer
HRM	High Rate Modem
hr	Hour
Hz	Hertz
ICD	Interface Control Document
IMCA	Integrated Motor Control Assembly
IMS	Inventory Management System
ISS	International Space Station
ITS	Integrated Truss Segment
IVA	Intravehicular Activity
JEM	Japanese Experiment Module

JEM–EF	Japanese Experiment Module–Exposed Facility
JEM–PM	Japanese Experiment Module–Pressurized Module
LDU	Linear Drive Unit
LEE	Latching End Effectors
LRDL	Low Rate Data Link
LRU	Line Replacement Unit
LSB	Least Significant Bit
LTU	Load Transfer Unit
MAEB	Materials Application and Evaluation Board
MAPTIS	Materials and Processes Technology Information
MBS	Mobile Remote Service Base System
MBSU	Main Bus Switching Unit
MCAS	Mobile Base System Common Attach System
MDM	Multiplexer/Demultiplexer
MLI	Multi–Layer Insulation
MIL-STD	Military Standard
M/OD	Meteroids/Orbital Debris
MRDL	Medium Rate Data Link
MSFC	Marshall Space Flight Center
MSS	Mobile Servicing System
MT	Mobile Transporter
MUA	Materials Usage Agreement
MUT	Multi–Use Tether
MWS	Mini–Workstation
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NSTS	National Space Transportation System
OIU	Orbital Interface Unit
OLR	Outgoing Long–wave Radiation
OOM	On–Orbit Maintenance

ORU	Orbital Replacement Unit
PAH	Payload Accommodations Handbook
PAS	Payload Attach System
PCS	Portable Computer System
PD	Payload Developer
PDGF	Power and Grapple Fixture
PEHG	Payload Ethernet Hub/Gateway
PEP	Payload Executive Processor
PFR	Portable Foot Restraint
POIC	Payload Operations Integration Center
PRLA	Payload Retention Latch Actuators
PSRP	Payload Safety Review Panel
PV	Photovoltaic
QD	Quick Disconnect
RPC	Remote Power Controller
RPCM	Remote Power Control Module
RSA	Russian Space Agency
RSU	Roller Suspension Unit
RT	Remote Terminal
RTL	Ready–To–Latch
RWS	Robotic Workstation
S3	Starboard 3
SDGF	Standard Dexterous Grasp Fixture
SEE	Single Event Effect
SEU	Single Event Upsets
SPDM	Special Purpose Dexterous Manipulator
SRMS	Shuttle Robotic Manipulator System
SRU	Shop Replacement Unit
SSME	Space Shuttle Main Engine
SSMMU	Solid State Mass Memory Unit

SSP	Space Station/Shuttle Program
SSRMS	Space Station Remote Manipulator System
TBD	To be Determined
TERA	Temporary Equipment Restraint Aid
TUS	Training Umbilical System
UCC	Universal Cargo Carrier
UCCAS	Universal Cargo Carrier Attach System
UMA	Umbilical Mechanism Assembly
U.S.	United States
USOS	United States On–orbit Segment
V	Volts
VC–S	Visible–Clean Standard
Vdc	Volts direct current

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APPENDIX B
GLOSSARY OF TERMS

Alignment Marks	Straight or curved lines of sufficient length and width to allow alignment, are applied to both mating parts, align when the parts are in the installation position, and are visible during alignment and attachment.
Ancillary Data	A selected subset of core systems data and other onboard generated data (including payload generated data) required to support experiment/payload analysis by users, for use by on–board payloads during operation, and for analysis of payloads by ground controllers as required. Ancillary data describes the flight environment in which the payload is operated.
Attached Payload Developer	Person or organization with overall responsibility for an Attached Payload, and/or user of science data generated by that payload’s operations.
Automatic (Capability)	Those functions, actions, responses, or operations that can be initiated, conducted, and completed by inherent equipment functionality. Automatic capability excludes any required human interaction with command and control workstations prior to execution of the function by the equipment, as well as physical reconfiguration of hardware during execution of the function.
Cargo Element	A flight element that has physical, functional, or both interfaces to the Orbiter (i.e., ITS, LAB, NODE, UCC, ORU, MPLM)
Catastrophic Hazard	A hazard which causes loss of on–orbit life sustaining system function.
Component	A particular hardware item within a system; e.g., a pump, a valve within a pump, an electrical power distribution box, etc.
Container	The standard container (housing) in which the payload or experiment resides.
Contingency	Any condition which results in, or may result in, the non–recoverable loss of a Station Critical Function.
Contingency Maintenance	Maintenance that is required to be performed without planned resources available.

Controllers	Individuals who conduct real time, non–real time, and sustaining engineering ground operations in support of Station increment operations.
Core Systems	Onboard Station hardware and software systems which provide Station resources, e.g., power, thermal cooling, data management, environmental control and life support, guidance and navigation, propulsion, communications and tracking, structures and mechanisms.
Corrective Maintenance	Maintenance performed to restore system hardware integrity following anomalies or equipment problems encountered during system operations or as a result of conditions discovered during preventive maintenance.
Crew	Individuals who operate and maintain the Station systems and payloads on–orbit in support of Station increment operations.
Critical Function	A function required to support a stable, habitable and revisitable station.
Critical Hazard	Any hazard which may cause a non–disabling injury, severe occupational illness, loss of emergency procedures or involves major damage to one of the following: the launch or servicing vehicle, manned base, an on–orbit life–sustaining function, a ground facility or any critical support facility.
Current Limiting	The current is limited to a specific level plus or minus a percentage for tolerance.
Depot Level of Maintenance	The designated maintenance level which has the capability to perform corrective and preventive maintenance of ORUs/LRUs/SRUs and designated equipment utilizing support equipment, facilities, personnel, and skills that are not economically available at other maintenance levels. The depot maintenance includes repairing, overhauling, modification and calibration of equipment.
Failure	The loss of function or functional redundancy. Specifically: the inability of a system, subsystem, string, ORU, component, or part to perform its required function(s) within specified limits.

Function	A separate and distinct action required to achieve a given objective, to be accomplished by the use of hardware, computer programs, personnel, facilities, procedural data, or a combination thereof; an operation that a system must perform to fulfill its mission or reach its objectives.
Ground Maintenance Personnel	Individuals who perform ground organizational level ORU/LRU and depot level repair in support of increment support operations.
Ground Processing Personnel	Individuals who perform prelaunch/postlanding processing for Station elements, systems, and payloads in support of increment support operation.
Ground Support Equipment	That deliverable equipment, both hardware and associated software/procedures, which is used, on the ground only, to provide some means of support to flight systems or equipment. GSE includes test and checkout equipment, handling and transporting equipment, access equipment, and servicing equipment.
Hazard	The presence of a potential risk situation caused by an unsafe act or condition.
In Situ Maintenance	Maintenance performed at the location of the failed item/function.
Intermediate On–Orbit Level Of Maintenance	The designated on–orbit level of maintenance that is responsible for corrective and preventive maintenance of ORUs removed from their installed location. Item failures are normally repaired by disassembly, repair and reassembly of the item. Intermediate maintenance is considered the middle level of maintenance and supports the organizational on–orbit level of maintenance.
International Partner	When used in this document, refers to RSA, ESA, NASDA and CSA.
Item	Any level of hardware assembly such as system, subsystem, equipment, component, segment of a system, assembly, subassembly, or a part.
Levels of Maintenance	Designation of sites where maintenance is performed based on the capabilities and resources available. For Station these levels have been designated as: (1) organizational on–orbit, (2) organizational on–ground, (3) intermediate on–orbit, and (4) depot.

Line Replaceable Unit	An item which can be removed from a ground system and replaced as a unit at the organizational on–ground level of maintenance.
Logistics	The management, engineering, and technical activities concerned with determining requirements, system design, and supplying and maintaining resources to support objectives, plans and operations.
Logistics Support Analysis	An iterative, analytical process through which support considerations impact system and equipment design, and operational support resources and requirements are identified.
Maintenance	The function of keeping items or equipment in, or restoring them to a specific operational condition. It includes servicing, test, inspection, adjustment/alignment, access, assembly/disassembly, lubrication, operation, decontamination removal, replacement, installation, fault location, calibration, condition determination, repair, modification, overhaul, rebuilding and reclamation. Maintenance includes preventive, corrective, in–situ and contingency maintenance both on orbit and on the ground.
Maintenance Concept	Narrative description identifying the broad, planned approach to be employed in sustaining the system/ equipment at a defined level of readiness or in a specified condition in support of the operational requirements.
Mode	A group of related function, with associated entry and exit rules, required to accomplish specific operations of the system.
Multi–Segment	An operation of product which affects more than one partner’s segment (NASA, RSA, ESA, NASDA and CSA all supply segments for the Station).
Operate	Perform intended design functions given specified conditions.
Orbital Replaceable Unit	An item which can be removed and replaced at the organizational on–orbit level of maintenance.

Organizational Ground Level Of Maintenance	The designated ground level of maintenance that is responsible for corrective and preventive maintenance of ground support equipment and systems during ground processing. Systems failures are normally corrected by removing and replacing failed items (ORU/LRUs) or in situ repair.
Organizational On–Orbit Level of Maintenance	The designation on–orbit level of maintenance that is responsible for orbital systems corrective and preventive maintenance. System failures are normally corrected by removing and replacing failed items (ORUs) or in situ repair. Maintenance performed on–orbit by crew members on installed system or element flight hardware in either pressurized or unpressurized environments. This level includes internal and external maintenance performed by: external robotic capability, EVA human, external robotic/EVA human cooperative, and IVA human.
Pallet	The structure (adapter plate) at each site to accommodate attached payloads.
Partner	Any one of NASA, ESA, NASDA, CSA or RSA.
Payload	If not otherwise modified, ”payload” in this document refers to a User payload or a UCC.
Payload Integration	Process for planning and preparing a payload complement for operation on the station, including payload complement selection, integration analysis and product development, safety certification, verification, payload operations planning, payload procedure development and the installation of the payloads into the logistics elements and Space Station.
Preventive Maintenance	Scheduled routine maintenance actions performed on equipment which is operating within specification and requires periodic maintenance to continue satisfactory performance or preclude functional failure.
Reconfiguration	Alteration of the currently active system components to establish a new vehicle configuration. The new system configuration may be the direct result of a failure, or in anticipation of changing vehicle support (i.e., prepare for mission support or recovery from a failure).

Reconfigure	The process of developing and installing the necessary updates that allow a changeout of data bases, software, hardware, interfaces, etc. that drive the configuration of facilities/systems.
Retry	Reinitializing a previously failed ORU or function or reinitializing services to the function in an attempt to recover the function.
Safe	Bring an item or system to a predefined configuration which eliminates or controls hazards to the crew, station and/or equipment.
Safety Critical	Having the potential to be hazardous to the safety of hardware, software and personnel.
Servicing	Activities performed on Attached Payload equipment which facilitate or enhance support to operational objectives. These activities may involve the assembly, check out, resupply, maintenance or upgrade of hardware and consumables, as well as the recovery of materials for return to earth.
Shop Replaceable Unit	Any item/subassembly of an Orbital Replaceable Unit/Line Replaceable Unit (ORU/LRU). Normally associated with items removed from ORUs/LRUs in intermediate and depot shops.
Shuttle Payload	Equipment or material carried by the Shuttle that is not considered part of the basic Shuttle itself.
Support Equipment	Equipment used to transport, handle, support, protect, maintain, monitor or service Station flight hardware/software, on–orbit or on the ground. Deliverable Support Equipment is categorized as Flight Support Equipment, Orbital Support Equipment and Ground Support Equipment.
Sustaining Engineering	Activities performed to keep the Station within design specifications or return it to design specification. Includes Station performance analysis, systems analytical model maintenance, systems performance assessment and system modification development and integration.
Training Facility	The structure housing a training device, classrooms, study areas, training support areas, shop areas, storage, etc.

United States Operations Center	A NASA provided user operations facility with a direct interface to the POIC for the purpose of planning coordinating and performing Space Station payload operations.
User	An entity that utilizes Station resources for the purpose of scientific research or development of commercial products.
User Payload	Equipment designed and developed for the purpose of performing research on board the on–orbit Space Station that is not considered part of the Space Station system.

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